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(March, 1958)

Review

SCIENTIFIC ASPECTS OF THE METHOD OF PRE-SOAKING SEEDS IN SOLUTION OF SALTS FOR GETTING INCREASED YIELDS OF CROP PLANTS*

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The idea of getting increased yields by soaking seeds of crop plants in solution of nutrient salts dates back as far as 1661, when Digby [1661] claimed to have obtained plentiful harvest of corn by soaking the seeds in solutions of saltpetre and other substances. This line of work was followed by Campbell [1843] who claimed a remarkable increase in yield by soaking seeds of barley, oats, etc. in solutions of ammonium salts while Schlesh [1907] and Eberhart [1907] found increases in yield by allowing the seeds to imbibe water only. Mercier [1919] in his book on the electro-chemical treatment of seeds has reported increases in yield of various crop plants. It was Kid and West [1918-1919] who in a series of articles, examined the scientific aspects of such seed treatment experiments quoting about 200 authors and they reached the important conclusion that factors which influence the plant during the early stages of development may have more or less pronounced effect on its subsequent life history. These factors are size of the seed, degree of its maturity, soaking seed in water, temperature and the effect of chemical treatment such as soaking the seeds in solution of salts and acids before sowing.

Kid and West [1919] have shown that the size of seed influenced the growth of the plant and this is to be expected as the amount of reserve food material in the seed varies. The effect of any treatment is, therefore, likely to be obscure or misleading due to variability in the food reserve from seed to seed.

Similarly, the degree of maturity of seeds has also been found to exercise great influence on the plant produce. It is, therefore, necessary that the seeds taken for experimentation must be of the same harvest. A rigid selection of the seeds is, therefore, essential to avoid variability in age, vigour and degree of maturation and storage conditions in these seed treatment experiments.

Soaking of seeds in water alone may produce either beneficial or deleterious effect on the growth of the plant. The adverse effect is caused by what is called soaking injury. Though the treatment of soaking seeds in pure water prior to sowing appears so simple, the immediate as well as subsequent effects produced by it are complex ; these effects would vary according to the conditions under which the treatment is carried out. When the seeds are immersed in water they are subjected to

*The results reported in this article have been obtained in the scheme for Cotton Physiological Research financed by the Indian Central Cotton Committee.

an abnormal condition—an exosmosis of reserve substances from the seeds to external water. There is also a decrease in oxygen supply of the seed and accumulation of carbondioxide in the seed. The extent to which these abnormal conditions would develop depends on the soaking period, temperature, relative amount of water used, density of seed mass, etc. In many cases it was found that pretreatment of seeds with pure water resulted in a decrease in germination and yield. The beneficial effects produced on plant development as reported by various workers has so far remained unexplained. It is possible that the various precautions noted above may not have been heeded. Before this problem is investigated it is, therefore, necessary to standardise the conditions for the treatments.

Soaking in water very probably alters the physiological conditions of the embryo. It may also liberate enzymes, thus rapidly increasing the production of soluble food nutrients ; the whole system is already in motion so that when the seeds are sown, developmental processes go on more rapidly than in the case of unsoaked seeds. This early start in life may ultimately reflect in growth and yield.

It is, therefore, necessary first to determine the optimum conditions such as the volume of water in proportion to the seed mass, the temperature, the duration of soaking, before any reliable results can be expected.

The micro-chemical investigations of the embryo after the water soaking treatment may reveal changes, chemical as well as physical, brought about in the cells, under a particular set of conditions. If any change that may occur in the cells can be detected, it may go a long way for the elucidation of the whole problem.

After the publication of the articles by Kid and West [1919], various workers have tried the method of presoaking seed in solution of nutrient salts to get an increase in yield. Tincker [1925], Jones and Tincker [1926], Smith and Bressman [1930], Novikov Sadouskajee [1939], Gousen [1940], Bequeral and Roussea [1947] and Roberts [1948] carried out extensive trials using solution of potassium hydrogen phosphate and concluded that relatively large quantities of mineral substances can be supplied by soaking seeds in the salts of those deficient elements though the quantities may not supply the total need of the crop. Significant increases were obtained by soaking seeds of oats, but not barley, in pure water. Similar seed soaking trials with rice have been conducted by Ramiah and he observed increase in yield by soaking seeds in pure water as well as potassium phosphate solution. Similar results have been obtained with cotton seed at Indore but the results were not consistent.

When the seeds are soaked in solution of nutrient salts, the effect of soaking in water as compared to the effect of the solute alone has also to be determined ; secondly, for the absorption of salt by such seed soaking treatments, the seed coat and the embryo will have to be considered separately as it is already known that the salts penetrate as far as the testa alone. Kotowski [1926] first pointed out that intake of salts depends on the nature of the seed and the cations and anions of the salt. The intake of ions varies from seed : to seed, some seeds may take in more ions than the others, even though other conditions may be constant,

No effort has been made to see whether the ions actually penetrate the living embryo. Roberts [1948] has given some estimations in case of husk and grain of untreated, water soaked and phosphate soaked wheat seeds. The seeds were also kept in running water for one hour after they had been soaked in phosphate solution as a separate treatment. Determinations of phosphate content under these different treatments indicated that phosphate has mostly penetrated the husk and can be washed out by keeping it in running water. The phosphate ions thus penetrated the living embryo to a negligible extent, as compared to the quantity of phosphate present in the grain itself.

Kotowski [1926] measured the uptake of ions by measuring a change in the electrical conductivity of the salt solution before and after the seeds were soaked. This method did not appear to be reliable as when the seeds were soaked, exosmosis of the soluble food material from the seeds to the external solution occurred. This introduced an error in the determination.

The most exhaustive work has been done on the effect of immersing the seed in solution of copper sulphate of different concentrations on germination and growth of plants and it was found that no satisfactory evidence could be obtained to show that there was an increase in vigour of the seedlings from such seeds. In some cases the effect produced was definitely harmful.

Besides the nutrient salts, solutions of many other substances were tried from different considerations in seed soaking trials. As the enzymes are required for breaking up reserve in soluble substances, experiments were tried by immersing the seeds in dilute solutions of diastase, trypsin, papyotin, etc. so that the enzymes may be directly available to the seeds. It is not, however, established whether the enzymes penetrated the embryo or not. The results obtained in such experiments were also not conclusive.

Some workers supplied the seeds directly with the products which are likely to result in the breakdown of food reserves in the seeds. Experiments were conducted, using solutions of various sugars, but the observation on seeds soaked in glucose or cane sugar solutions was not extended beyond the germination tests.

The liberation of enzymes in the seeds also was sought to be produced by keeping the seeds in solutions of strong inorganic acids like sulphuric acid or weak acids like tartaric, acetic, oxalic and boric acids but such treatments were found to produce beneficial effects on germination and subsequent plant development in some cases alone.

The underlying idea of all the physical and chemical treatments of seeds is that the conditions operating during the germination and the early seedling stage of the life cycle of the plants are of great importance, as they exercise a predetermining influence on subsequent growth and yield. A correlation between the vigour of seedlings and that of the adult is already known to exist and seed treatment experiments with a view to increase the vigour of the seedlings, have been attempted in the past with non-conclusive results.

When the seeds are soaked in a salt solution, the diffusion of an electrolyte through the impermeable membrane into the embryo does not take place, until the charge on the membrane is not neutralised by the absorption of oppositely charged ions. The absorption of an ion will also depend on the degree of the dissociation constant of the salts, at a particular dilution. These facts will have to be taken into account when adopting the seed soaking treatment with a salt solution.

Solutions of other substances like iodine, tri-chloroacetic acid, phenol, silver nitrate, sodium chloride and the dyes are used for seed treatments and their penetration into the seed is followed microscopically. It is found that the solute penetrated only as far as the cuticular membrane.

Similarly, other organic substances like trichloro-ethylene, ethylene chloride, ethyl bromide, salts of thiocyanate, carbon-disulphide have been tried. It was found that the number of heads produced by wheat by treatment with potassium thiocyanate and ethyl bromide were higher than in the wet control. These substances are generally used for breaking dormancy of the potato tubers or hastening the ripening process of fruits. Compounds with small molecules like alcohol and phenols have also been tried but they were not found to penetrate the seeds until the absorption of water from the solution of these substances occurred. No absorption of alcohol was found to occur, when the seeds were immersed in absolute alcohol.

The effect of hormone treatment on plant growth and yield has been a subject of active investigation since 1936 and various claims have been made regarding the beneficial effect of such treatments on the yield. And the commercial preparations like Grain and Staymore were advertised for seed treatments for increasing the yield. These claims have not been supported by various workers like Kiesselbach [1943].

Recently Kruyt [1954] has summarised the work done on this aspect of the seed treatment and he himself carried out detailed investigations on the effect of hormonisation of the seeds. He has concluded that the treatment of seeds for the purpose of stimulating growth and development by synthetic plant-growth regulating substances has not given any practical results, on account of the different ways in which the problem has been tackled and differences in the seeds used. Hence no definite conclusions could be reached. As pointed out before, a knowledge of biochemical changes occurring in the cells during germination is necessary to understand the effect produced by a growth regulating substance, by water absorption or by any electrolyte during the initial stages of germination.

Material and Methods

In order to find out whether the ions of salts penetrate the embryo, some experiments were conducted with cotton seeds in the Cotton Physiological Research Scheme financed by the Indian Central Cotton Committee. The salts of both major and minor elements were utilised, and amongst the major elements potash, phosphoric acid and nitrates in the form of potassium nitrates and potassium hydrogen phosphate were used. The concentrations of potassium nitrate used were M/50

and M/100 and those of potassium hydrogen phosphate were M/2, M/4, M/50, and M/100. The soaking period was six hours : 226 gm. of seeds were soaked in 500 cc. of each salt solution. Control was kept by soaking seeds in distilled water for the same period. After soaking, the testa and embryo were separated out by hand and they were analysed for these ions. Side by side the analysis of the whole seed was also carried out. Tables I, II and III give the results of these determinations with the American cotton.

TABLE 1

Potassium Nitrate in two concentrations

Variety—Indore 1 Soaking time=6 hours

	Percentage of nitrogen			Percentage of potash		
	M/50	M/100	Water soaking	M/50	M/100	Water soaking
Embryo	6·03	6·02	5·80	1·267	1·255	1·232
Testa	0·909	0·861	0·732	0·717	0·691	0·667
Whole seed	3·53	3·51	3·48	1·076	1·052	0·996

TABLE II

Potassium hydrogen phosphate KH_2PO_4 in two concentrations

Variety—Indore 1 Soaking time=6 hours

	Percentage of potash			Percentage of phosphoric acid		
	M/50	M/100	Water soaking	M/50	M/100	Water soaking
Embryo	1·288	1·255	1·237	2·297	2·279	2·330
Testa	0·686	0·692	0·682	0·237	0·225	0·236
Whole seed	1·031	1·023	0·983	1·400	1·385	1·361

TABLE III

Potassium hydrogen phosphate KH_2PO_4 in two concentrations

Variety—Indore 1 Soaking time=6 hours

	Percentage of potash			Percentage of phosphoric acid		
	M/2	M/4	Water soaking	M/2	M/4	Water soaking
Embryo	1·395	1·348	1·237	2·499	2·457	2·330
Testa	1·348	0·994	0·682	0·885	0·596	0·236
Whole seed	1·441	1·301	0·983	1·876	1·649	1·361

Nitrate ions appeared to have penetrated both the testa and the embryo to a small but equal extent as can be seen from the differences in the total nitrogen present in the testa and embryo of soaked seeds (Table I). There was a small increase of 0·2 per cent nitrogen in embryo as 5·8 per cent of nitrogen was found to be present in the embryo of the seed itself. The quantity thus supplied by this method is very negligible. It works out at 0·0008 gm. per seed. A cotton plant at Indore absorbs about 0·2 gm. of nitrogen from the soil. An additional amount of 0·0008 gm. by the method of seed soaking works out at 0·4 per cent of the total nitrogen taken from the soil by the cotton plant at Indore. Thus soaking seeds in the salts of this major element appears to be of little value and is not expected to have any effect on the growth of the seedling.

Potash ions did not penetrate either the embryo or the testa from the dilute solutions of either potassium nitrate or potassium hydrogen phosphate. There is already 1·23 per cent potash in the embryo of the seed of the untreated seeds while in the seed soaked in the salt solutions, the embryos were found to contain 1·25 to 1·23 per cent of potash. Similar is the case with the testa. When concentrated solutions of potassium hydrogen phosphate were used the potassium concentration of the testa was increased by 0·3 to 0·7 per cent and of the embryo by 0·1 to 0·15 per cent. The quantity of potash thus supplied by this method will also be very small to what is absorbed from the soil.

The trend in the quantity of phosphate ions that penetrate the testa and embryo are similar to those discussed above for potash. Phosphate ions are not found to penetrate either the testa or the embryo from the dilute solution of potassium hydrogen phosphate. From higher concentration, absorption increases as the concentration increases. The quantity that has been found to penetrate was nearly the same as was the case with potash.

Experiments with salts of minor elements

Experiments were also conducted to determine the quantity of ions of minor elements absorbed from the solutions of their salts of different concentrations. The salts used were chromium sulphate $Cr_2(SO_4)$ 3 $5H_2O$, manganese sulphate $MnSO_4 4H_2O$ and copper sulphate $CuSO_4$ $5H_2O$. In the case of chromium and manganese sulphate the concentrations used were M/50 and M/100, while in the case of copper the concentrations used were M/4 and M/8. The soaking period was 6 hours in the case of chromium and manganese and 12 hours in the case of copper.

Table IV

Salt Cr_2 (SO_4) 3 $5H_2O$ chromium sulphate

Chromium in p.p.m.

Variety—Jaydhar Soaking time=6 hours

——	M/50	M/100	pure water
Embryo	Trace	*nil*	*nil*
Testa	1452	1063	*nil*
Whole seed	676	353	*nil*

Table V

Salt $MnSO_4$ $4H_2O$ manganese sulphate

Manganese in p.p.m.

Variety—Jaydhar Soaking time=6 hours

——	M/50	M/100	pure water
Embryo	134	69	27
Testa	3580	2138	31
Whole seed	1954	1280	44

Chromium was not found to be present either in the testa or the embryo of the cottonseed, but a fair amount of manganese was found to penetrate the embryo as can be seen from Table V. This was a new conclusion.

Chromium ions appeared to penetrate up to the testa only. The quantity increased as the concentration of the solution increased but it did not enter into the cells of the embryo. When immersed in M/50 solution, the behaviour was found to be different with manganese ions. The testa contained after a soaking period of 6 hours 3580 p.p.m. of these ions, while the embryo contained 134 p.p.m. of the same ion. It is possible that by increasing the soaking period and using higher concentrations, more of manganese ions would penetrate the embryo. It needs to be determined whether the germinating power of such soaked seeds was in any way adversely affected, by prolonging the soaking period and by using higher concentrations.

TABLE VI

Salt $CuSO_4$ $5H_2O$ copper sulphate

Copper in p.p.m.

Variety—Indore 1 Soaking time=12 hours

	M/4	M/8	Pure water
Embryo	1751	1552	17
Testa	9518	10590	12
Whole seed	5930	6192	13

As the concentrations used were higher and soaking period was 12 hours instead of six hours, copper has penetrated both the testa and the embryo to a very great extent. The quantity of copper that enters the embryo appears to be fairly high and this method may meet partly the demand for this trace element by the cotton plant.

It thus appears, copper and manganese requirements of the cotton plant can partly be met by the seed soaking method if the high concentration and larger duration of the soaking period do not affect the germinating capacity of the treated seeds. This problem is under investigation at present. It is not determined as to what are the functions of trace elements in the growth of the cotton plant, and until this is known no conclusions regarding the effectiveness of this seed soaking method in providing the minor elements to the plant, can be drawn.

It is also clear from the above experiments that by presoaking seeds in salts of major elements, very minute traces of these elements seem to penetrate the embryos of the cotton seed and it is not likely that these traces that penetrate may give any beneficial effect to the developing seedlings in the early stages of growth. It is, therefore, all the more necessary to work under uniform conditions, if any definite conclusion regarding the effect of seed soaking treatment is to be obtained. The variability due to age, size or weight and maturity from seed to seed must, therefore, be reduced to a minimum, by proper selection of seeds.

The investigations so far conducted have not taken all these factors into consideration. Most of these experiments appear to be empirical in nature and seeds without considering their age, size, or degree of maturity, are soaked in chemical solutions and the effects of such treatments has been studied. Volume of water to the seed mass and temperature have also not been taken into account and they have varied from experiment to experiment. It is, therefore, not unexpected that very complex and inconclusive results are obtained. The investigation needs, therefore, to be conducted taking into account all these factors.

The main object of this short note is to focus attention on the physiological and biochemical aspects of such experiments of presoaking seeds in nutrient solutions before the yield trials are undertaken. As such trials are being conducted by various workers, it is suggested that the scientific aspects briefly mentioned may be first considered before the effect on the yielding capacity of a crop is tested. Though the operation of seed soaking is simple and the idea of increasing the yield attractive, the physico-chemical changes, that are brought about by such treatments, appear to be complex and little understood.

This article contains the results of a preliminary investigation. Detailed investigations on this problem as indicated above are to be carried out in a new scheme sanctioned by the Indian Council of Agricultural Research at Indore, Delhi and Almora.

Summary

The previous literature is reviewed and the various factors that should be taken into account in experiments to study the effect of presoaking seeds in nutrient salts and other chemical substances are pointed out. The factors to be considered are size and maturity of seed, the date of harvest, storage conditions, the period of soaking, the proportion of seed mass to the volume of water, the solution used for soaking andthe effect of the solvent as compared to the effect produced by the solute. The permeability of seed coat is an important factor as it is found to vary from seed to seed.

The entry of ions of major and minor elements in the testa and the embryo is studied to determine as to what extent these nutrients become available to the developing embryo when the seeds are soaked in the solutions of their salts. It was found by analysing the testa and embryos of cotton seeds, that none of the major elements like nitrogen, potash or phosphate penetrated the embryo. The case was different with salts of minor elements. Manganese and copper were found to be present in the embryos in considerable quantities after the seeds were soaked for six or twelve hours in solutions of different concentrations.

REFERENCES

Albaum, H. G.; Kaiser S.; Eichel, B. (1940). Coleoptile growth after preliminary soaking of oat grains. *Amer. Jour. of Botany* **27**, 619

Bailey William Marshall (1933). Structural and metabolic after-effects of soaking seeds of *Phaseolus*. *Bot. Gaz.* **94**, 688

Braun, Harry (1919). Presoaking as a means of preventing seed injury due to disinfectants and of increasing germicidal efficiency. *Science* **49**, 544

——— (1924). A gradient of permeability to iodine in the wheat seed coats. *J. Agric. Res.* **24**, 225

Brenchley, W. E. (1923). Effect of the weight of seed upon the resulting crop. *Ann. App. Biol.* **10**, No. 2, 223

Brown, A. J. (1907). On the existence of a semipermeable membrane enclosing the seeds of some of the Gramineae. *Ann. Bot.* **21**, 79

——— (1909). The selective permeability of coverings of the seeds of *Hordeum vulgare*. *Proc. Roy. Soc.* London B. **81**, 82

Brown, A. and Tincker F. (1915). The rate of absorption of various phenolic solutions by seeds of *Hordeum vulgare* and the factors governing the rate of diffusion of aqueous solutions across semipermeable membranes. *Proc. Roy. Soc.* B. **LXXXIX**, 119

Brown, A. and Worley (1912). Influence of temperature on absorption of water by seeds of *Hordeum vulgare* in relation to the temperature coefficient of chemical change. *Proc. Roy. Soc.* B. **LXXXV**, 546

Brown, Robert (1931). The absorption of water by seeds of *Lolium perenne* and certain other Gramineae *Ann. Applied Biolog.* **18**, 559

——— (1932). The absorption of the solute from aqueous solutions by the grain of wheat. *Ann. Bot.* **46**, 571

Christides B. G. (1936). Cottonseed treatment with H_2SO_4. *J. Agric. Sci.* **26**, 648

Coffman, M.A. (1923). The minimum temperature of germination of seeds. *J. Amer. Soc. Agro.* **15**, 257

Collins, E. J. (1918). The structure of the integumentary system of the barley grain in its relation to localized water absorption and semipermeability. *Ann. Bot.* Vol. **32**, p. 381

Crocker, W. (1906). Role of seed coats in delayed germination. *Bot. Gaz.* **XLII** No. 4, 265

Denny, F. E. (1917). Permeability of membranes as related to their composition. *Bot. Gaz.* **63**, 468

Degby, Sir Kenelm (1661). A discourse concerning the vegetation of plants. Second treatise (A discourse spoken at Gresham college on 23rd January (1660)

Eyster, H. Clyde 1938). Conditioning seeds to tolerate submergence in water. *Amer. J. Bot.* **25**, p. 33

——— (1940). The cause of decreased germination of water soaked bean seeds. *Amer. J. Bot.* **27**, p. 652

Glenn, A. Huber and Charles J. Gould (1949). Cabbage seed treatment *Phytopath.* **39**, 869

Harrington, G. T. (1923). Forcing germination of freshly harvested wheat and other cereals. *J. Agric. Res.* **XXIII** No. 2, 79

Harrington, G. T. and Crocker, W. (1923). Structure, Physical characteristics and composition of the pericarp and integuments of Johnson grass seed in relation to its physiology. *J. Agric. Res.* **XXIII** No. 3, 193

Harlan, H. V. and Pope, M. N. (1922). Germination of barley seeds harvested at different stages of growth. *J. Heredity* **XIII** No. 2, 72

——— (1923). Water content of barley kernels during growth and maturation. *J. Agric. Res.* **XXIII** No. 5, 333

Hwang, Y. and Pearse H. L. (1940). The response of seeds and seedlings to treatment with indolyl acetic acid. *Ann. Bot. New series* **4**, 31

Jones, Martin G. and Tincker, M. A. H. (1926). Yield studies in oats, the effect of the pretreatment of the parent crop upon the seed produced, its germination and subsequent growth. *Ann. Appl. Biol.* **13**, 535

Kenneth, V. Thimann and Lane R. H. (1938). After-effects of the treatment of seed with Auxin. *Amer. J. Bot.* **25**, 535

Kidd, F. (1914). Controlling influence of carbon dioxide in maturation dormancy and germination of seeds. *Proc. Roy. Soc.* B. **87**, p. 408

——— and West C. (1919), Physiological predetermination. Influence of Physiological conditions of the seed upon the course of subsequent growth and upon yield. *Ann. Appl. Biol.* No. 1

——and—— (1919). Influence of temperature on soaking of seed. *New Phytologist.* **XVIII** No. 1/2/35

Kiesselbach, T. A. (1943). Crop response to hormone seed treatment. *J. Amer. Soc. of Agro.* **35**, 321

Kotowski, F. (1926). Chemical stimulants and germination of seeds. *Proc. Amer. Scc. Horti. Sci.* **23**, 173

——— (1927). Semipermeability of seed coverings and stimulation of seeds. *Plant Physiology* **2**, 177

Kyle, C. H. (1916). The relationship of early growth to the yield of grain in corn. *J. Amer. Soc. Agro.* **VIII**, No. 3, 208

Leukel, R. W. (1948). Recent developments in seed treatment. *Bot. Rev.* **14**, p. 235

Livingstone, B. E. (1902). The role of diffusion and osmotic pressure in plants. Pool —(Chicago)

Machacek, J. E. and Wallace A. H. (1952). Germination of treated and untreated seed of wheat, oats and barley of different commercial grades. *Scientific Agriculture* **32**, 597

Marre, E., and Murneek, A. E. (1953). The effects of fertilization and growth regulating substances (Hormones) on carbohydrate and Hexose Phosphate metabolism during the early stages of growth of corn kernels (Fruit). *Science* **117**, 661

Nyron, Stout and Bion, Tolman (1944). Field and greenhouse tests with synthetic growth regulating substances applied to sugar beet seeds and plants. *J. Amer. Soc. of Agro.* **36**, 141

Orton, C. R. (1927). The permeability of the seed coat of corn to mercury compounds. *Phytopath.* Abstr. **17**, 51

Osterhout, W. J. V. (1912). The permeability of protoplasm to ions and the theory of antagonism. *Science* N. S. **35**, 112

Pratt Robertson (1938). Influence of Indole—3 Acetic acid on the respiration of growth of intact wheat seedlings. *Amer. J. Bot.* **25**, 389

Pugh, Grace W ; and Johan Helen. (1932). Relation of the semipermeable membranes of the wheat kernel to infection by Gibberella Saubinetti. *J. Agric. Res.* **45**, 609

Roberts, W. O. (1948). Prevention of mineral deficiency by soaking seed in nutrient solution. *J. Agric. Sci.* **38**, 458

Shull, C. A. (1913). Semipermeability of seed coats. *Bot. Gaz.* Vol. **56**, 169

Shull, C. A. and Shull S. P. (1924). Temperature coefficients of absorption in seeds of corn. *Bot. Gaz.* **18**, 212

Shull, C. A. (1930). The permeability of plant membranes to the Halogens--Communications to section P of the fifth International Botanical Congress Cambridge, 1930

Shull (1913). Semipermeability of seed coats. *Bot. Mag.* Sept. 1913

Simpson, D. M. (1946). The longevity of cottonseed as affected by climate and seed treatments. *J. Amer. Soc. of Agro.* **88**, 32

Smith, D. C. and Bressman (1930). Some effects of seed treatment on the germination and subsequent growth of wheat. *J. Agri. Res.* **40**, 25

Stewart Williams, S. and Charles, L. Hamner (1942). Treatment of seeds with synthetic growth regulating substances. *Bot. Gaz.* **104**, 338

Stiles, W. and Kidd, F. (1919). The influence of external concentration on the position of the equilibrium attained in the intake of salts by plant cells. *Proc. Roy. Soc.* London B. **90**, 448

——— (1919). The comparative rate of absoprtion of various salts by plant tissue. *Proc. Roy. Soc.* London BXC 487

Tharp, W. H. (1932). The influence of the maturation environment upon the permeability of the seed—coat of barley. *Amer. J. of Bot.* **19**, 836

——— (1935). Development anatomy and relative permeability of barley seed coats. *Bot. Gaz.* **97**, 240

Templeman, W. G. and Marmoy, C. J. (1940). The effect of watering with solutions of plant growth substances and seed dressings containing these materials upon the growth of plants. *Anna. Appl. Biol.* **27**, 453

Tincker, M. A. H. (1925). Physiological predetermination experiments with certain economic crops. The relation between rate of germination and subsequent growth. *Anna. Appl. Biol.* **12** p. 440

True, R. H. (1893). On the development of the Caryopsis. *Bot. Gaz.* **18**, 212

Tsung, Le Loo and Yu wei Tang (1945). Growth stimulation by manganese sulphate Indole—3 acetic acid and colchicine in the seed germination and early growth of several cultivated plants. *Amer. J. Bot.* **32**, 106

Wolfe, H. S. (1926). Absorption of water by barley seeds. *Bot. Gaz.* Vol. **82**, p. 89.

EFFECT OF DIFFERENT DOSES OF NITROGEN AND PHOSPHORUS—PLACED AND BROADCAST—AND OF ROW SPACINGS ON MAIZE

By R. D. Verma and J. C. Sharma

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BESIDES being a cereal of high yielding capability and nutritive value, both as feed and fodder, maize has become an important source of starch for the industry. The potentialities of this crop have been fully realized and exploited in other countries, particularly in America, where considerable amount of work has been done towards its improvement, with the result that the United States' present average of 29·1 maunds of maize per acre is very high compared to India's 8·3 maunds. Till recently, this crop received very little attention of the agricultural scientists in this country. However, at the Indian Agricultural Research Institute, New Delhi, systematic study of the effect of various agronomic factors has been in progress for some years past. The results of one experiment, in which five factors, viz. application of farmyard manure, different doses of nitrogen and phosphorus, different row spacings and methods of applying fertilizers have been studied, are reported in this article.

Material and Methods

The experiment was conducted at the Farm in the Division of Agronomy, Indian Agricultural Research Institute, New Delhi from 1949 to 1951. The layout was a slit plot design with two replications. The treatments were as follows :

Main-plot treatments

1. No farmyard manure
2. Farmyard manure at 4,000 lb. (equivalent to 20 lb. N) per acre

Sub-plot treatments

Combinations of spacings between rows :

1. 2 ft.
2. 2·5 ft.
3. 3 ft.

Methods of application of fertilizers :

(*a*) Placement

(*b*) Broadcast

Sub-sub-plot treatments

Combinations of doses of nitrogen (in the form of ammonium sulphate)

1. 20 lb. N per acre
2. 40 lb. N per acre
3. 60 lb. N per acre

Combinations of doses of phosphorus (in the form of superphosphate)

(*a*) 40 lb. P_2O_5 per acre

(*b*) 80 lb. P_2O_5 per acre

A basal dose of 20 lb. K_2O per acre applied as potassium sulphate was common to all the treatments. All the nutrients were applied at the sowing time. The placement was done in two side bands, 2·5 inches on each side of, and 1 inch below the seed row, by means of " poras" " or tubes attached to a ' horse hoe ' [Verma 1952].

The experiment was carried out on the same site every year and the treatments were applied every year to the same plots. The variety of maize was " Pusa yellow No. 2". Other agricultural operations were normal and uniform for all the treatments.

Results and Discussion

Main treatments

The effect of various treatments on the yield of maize grain is summarised in Table I.

Table I

Effect of main treatments on the yield of grain

Treatments	Yield in maunds per acre			
	1949	1950	1951	Average over 1949-51
No. F.Y.M.	22·17	24·80	15·40	20·79
F.Y.M. at 4,000 lb. per acre	23·83	25·84	16·52	22·06
SE_m	±0·25	±1·26	±1·56	±1·31
' F ' test	Not sig.	Not sig.	Not sig.	Not sig.
Row-spacings :—				
2 ft.	25·99	24·65	16·57	22·40
2·5 ft.	22·45	25·41	15·96	21·27
3 ft.	20·56	25·90	15·36	20·60
SE_m	±0·89	±0·55	±1·08	±0·46
' F ' test	Sig.	Not sig.	Not sig.	Not sig.
C. D. at 5 per cent	2·76	..	..	..
C. D. at 1 per cent	3·87	..	..	..
Methods of applying fertilizer : Broadcast	22·97	25·51	15·54	21·34
Placement	23·03	25·13	16·38	21·51
SE_m	±0·73	±0·45	±0·88	±0·38
' F ' test	Not sig.	Not sig.	Not sig.	Not sig.

TABLE I—*contd.*

Effect of main treatments on the yield of grain

Treatments	Yields in maunds per acre			
	1949	1950	1951	Average over 1949-51
Doses of nitrogen :				
20 lb. per acre	21·95	19·33	14·28	18·52
40 lb. per acre	23·14	23·54	16·53	21·07
60 lb. per acre	23·91	33·09	17·08	24·69
SE_m	±0·68	±0·38	±0·54	±0·32
'F' test	Not sig.	Sig.	Sig.	Sig.
C.D. at 5 per cent	..	1·08	1·52	0·88
C. D. at 1 per cent	..	1·44	2·00	1·17
Doses of phosphorus :				
40 lb. P_2O_5 per acre	22·98	25·01	15·61	21·20
80 lb. P_2O_5 per acre	23·02	25·63	16·30	21·65
SE_m	±0·55	±0·31	±0·44	±0·26
'F' test	Not sig.	Not sig.	Not sig.	Not sig.
Years :	23·00	25·32	15·96	21·43

SE_m = ±0·37 : 'F' test = sig. : C.D. at 5 per cent = 1·022 and at 1 per cent = 1·35.

Effect of season

It may be seen that the differences between the average yields of the three years are significant, showing that the season played an important role in determining the average yield of maize. It is evident from Table II that mainly it was the rainfall which influenced the yield considerably. In the year

1951, the general average came down to 15·96 maunds per acre because of very low rainfall, viz. 8·44 inches as compared to 23·00 and 25·32 maunds per acre in the first and the second year, when the amount of precipitation was 21·59 and 25·25 inches respectively.

TABLE II

Minimum and maximum temperature and rainfall during different years of crop season

Year and month	Mean maximum temperature °F	Mean minimum temperature °F	Monthly rainfall (inches)	Mean relative humidity (per cent)
1949—				
July	92·6	79·9	14·72	83·6
August	92·3	78·6	3·20	81·7
September	93·3	77·8	3·66	84·9
October	90·2	62·2	0·01	73·1
		TOTAL .	21·59	
1950—				
July	92·0	80·3	11·80	85·4
August	91·0	78·0	7·47	88·9
September	89·3	75·0	5·98	89·6
October	89·7	60·1	0·00	78·2
		TOTAL .	25·25	
1951—				
July	100·7	81·8	3·44	67·6
August	93·2	79·2	2·51	76·9
September	93·8	74·7	2·45	74·4
October	97·3	70·1	0·04	64·4
		TOTAL .	8·44	

Effect of nitrogen.

From Table I it will be observed that with increase in the dose of nitrogen, the yields have increased progressively. Except in the first year, the 40 and 60 pounds of nitrogen gave significant increases in the yield as compared to the lowest dose of 20 lb. nitrogen, the differences between the 20- and 60-lb. doses being highly significant. These results are in agreement with those obtained by many other workers like McVikar *et al.* [1947] : Paterson *et al.* [1949] : Luebs and Pumphery [1949] ; Harper *et al.* [1949] : Eskew and Paden [1949] and Howard *et al.* [1949]. Crowther *et. al* [1937] reported marked responses to nitrogen with all methods of sowing and all spacings. Similarly Black *et al.* [1945] secured highest total yields of maize with 40 lb. nitrogen as compared to 10 lb.

Effect of spacings

A high statistical significance in case of spacings was found in the year 1949 when highest yield was obtained from the closest spacing (2 ft.). The yield decreased with an increase in row-spacing (Table I). Similar trends were noticeable in 1951 and in the average of the three years. These results indicate that closer spacings were better than the wider ones. This was mainly due to the advantage of higher plant population in closely spaced rows, which resulted in greater number of ears and, therefore, higher yield.

Results similar to this have been obtained by Stringfield and Thatcher [1951], Muhr and Rost [1951] and many other workers.

Effect of other treatments[1]

The other treatments, namely, the application of farmyard manure, the double dose of phosphorus and the application of fertilizers by placement method, though slightly increased the yields as compared to their counterparts, did not show significant differences.

Interactions

On a statistical study of the combined results of the three years, it was found that three interactions, i.e., nitrogen × spacings, nitrogen × years and year × spacing were significant. The results are given below :

Nitrogen × spacing. The data for this interaction are presented in Table III.

TABLE III

Effect of spacings in combination with the doses of nitrogen

Treatments	Yields in maunds per acre		
	20 lb. nitrogen	40 lb. nitrogen	60 lb. nitrogen
2-feet spacing	18·96	21·70	26·54
2·5 feet spacing	18·65	21·66	23·52
3 feet spacing	17·94	19·85	24·02

S. $E_m = \pm 0{\cdot}55$; C. D. at 5 per cent = 1·53, and at 1 per cent = 2·02

The highest dose of nitrogen (60 lb.) in combination with the closest spacing (2 ft.) gave the maximum yield. It would appear that this dose provided adequate nutrition to the larger plant population obtained due to the 2-foot spacing and led to a fair relationship between the nutrient supply and the plant population, and consequently resulted in the maximum output. Similar results were obtained by Krantz [1949] and other workers who tried many spacings and plant populations at various fertility levels.

Nitrogen × *year.* The relevant data are presented in Table IV.

TABLE IV

Effect of doses of nitrogen in different seasons

Treatments	Yields in maunds per acre		
	20 lb. nitrogen	40 lb. nitrogen	60 lb. nitrogen
Year			
1949	21·95	23·14	23·91
1950	19·33	23·54	33·09
1951	14·28	16·53	17·08

S. $E_m = \pm 0{\cdot}63$; C. D. at 5 per cent = 1·77, C. D. at 1 per cent = 2·34.

It has already been said under the head " Effect of season " that the season manifested its effect significantly. From Table IV it is clear that an increase in the dose of nitrogen from 20 to 40 lb. per acre led to a substantial increase in the yield in all the three years resulting in significant differences in 1950 and 1951. The response to a further increase in the dose of nitrogen, however, appears to be conditioned by the amount of rainfall as is apparent from the figures for 1951, where the high amount of rainfall coupled with uniform distribution seems to have afforded a better utilisation of the highest dose of nitrogen (60 lb.) than in the other two years. Krantz [1949] stated that the degree of response to the application of nitrogen was influenced mainly by climatic conditions.

Year × *spacing.* It will be seen from Table V that significant differences between the three spacings were observed only during the year 1949. The yields decreased as the spacings were widened. A similar trend was noticed during 1951. The results in 1950 were, however, not similar ; wider spacings have given slightly, though not significantly, better yields than the closer spacings.

TABLE V

Effect of spacings in different seasons

Treatments	Yields in maunds per acre		
	1949	1950	1951
2-feet spacing	25·99	24·65	16·57
2·5 feet spacing	22·45	25·41	15·96
3 feet spacing	20·56	25·90	15·36

S. $E_m = \pm 0{\cdot}63$, C. D. at 5 per cent = 1·77, C. D. at 1 per cent = 2·34.

SUMMARY

A factorial experiment to study the effect of three spacings –2, 2·5 and 3 feet ; three doses of nitrogen—20, 40 and 60 pounds per acre applied as ammonium sulphate ; two doses of phosphorus 40 and 80 pounds per acre applied as superphosphate; farmyard manure at the rate of 4,000 lb. per acre vs. no farmyard manure and of placement and broadcast methods of applying fertilizers on maize, was carried out from 1949 to 1951 in the Division of Agronomy, Indian Agricultural Research Institute, New Delhi. The results are as follows :

The average yields of the three years differed significantly—varying directly with the amount of rainfall received in that year. The yields in general increased with higher amount of rainfall. An evenly distributed rainfall of about 25 inches seemed most favourable.

The average yields showed a progressive and significant increase with each successive increase in the rate of nitrogen application.

In 1949, the yields from 2-, 2·5- and 3-foot spacings were 25·99, 22·45 and 20·56 maunds per acre respectively— increasing significantly as the spacing was reduced. Similar but non-significant trends were also shown in 1951 and in the average of the three years.

The highest dose of nitrogen (60 lb.) proved best in combination with the closest (2 ft.) spacing.

The highest dose of nitrogen (60 lb.) was most effective in 1950, when the rainfall was maximum 25·25 inches.

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REFERENCES

Black, C. A., Pierre, W. H. and Lawton, K. *Iowa Agri. Exp. Sta. Rpt.* 1944-45 : 21-33

Crowther, F., Tomforde, A. and Mahmoud Ahmed (1937). Experiments in Egypt on interaction of factors in crop growth. *Roy. Agric. Soc. Egypt, Bull.* **28**

Eskew, E. B. and Paden, W. R. (1949). Influence of high rates of nitrogen in corn. *Nat. J. C. Fert. Appl. Proc. Ann. Meet.* **24** : 61-63

Harper, H. J. and Brensing, O. H. (1949). Effects of ammonium nitrate on corn. *Amer. Fert.* **110**(3) : 11, 24, 26, 28

Howard, R. E. and Smith, F. W. and Roscoe, E. (1949). *Nat. J. C. Fert. Appl. Proc. Ann. Meet.* **25**

Krantz, B. A. (1949). Fertilizating corn for higher yields. *N. Carolina Agric. Exp. Sta. Bull.* **366**

Luebs, A. E. and Pumphery, F. V. (1948). Fertilizers for irrigated corn. *Nat. J. C. Fert. Appl. Proc. Ann. Meet.* **24** : 56-58

McVikar, M. H. *et al.* (1948). Corn fertilizer experiments. *Nat. J. C. Fert. App. Proc. Ann. Meet.* **23** : 149-54

Muhr, G. R. and Rost, C. O. (1951). The effect of population and fertility on yield of sweet corn and field corn. *Agron. J.* **43**(7) : 315-19

Paterson, V. H., Jones, H. E. and Smith, F. W. (1949). Corn fertilizer studies in Kansas. *Nat. J. C. Fert. App. Proc. Ann. Meet.* **24** : 47-51

Stringfield, G. H. and Thatcher, L. E. (1951). Corn row spaces and crop sequence. *Agron. J.* **43**(6) : 276-81

Verma, R. D. (1952). A simple device for the placement of fertilizers. *Indian Fmg.* **2** ; No. 4

OCCURRENCE OF A PHOSPHORBACTERIUM IN THE GLANDS OF *CASSIA OCCIDENTALIS*

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(With 1 Text-Figure)

Pikovskaia [1948] isolated, from soils and phosphorites, an organism capable of actively decomposing calcium phosphate with the formation of water soluble phospate. This organism was termed ' Bacterium P '. Similar cultures of azotobacter, clostridium and nitrifiers produced phosphates soluble in 0·002 N acid but not in water. The property of solubilising insoluble phosphates seemed subsequently to be possessed by many other organisms as well. From soil cultures, Menkina [1950] isolated a new strain of *B. megatharium* var. *phosphaticum* and a new variety of *Serratia* var. *phosphaticum* which were specific for mineralisation of organic phosphates.

During search for some nitrogen fixing organism in some part of the ordinarily non-nodulating legume *Cassia occidentalis*, the authors came across an organism in the glands of the plant. The tiny red glands attached to the petioles were found to harbour the organism which was, however, devoid of any capacity for fixation of atmospheric nitrogen. The organism was invariably observed in the glands of the plant irrespective of the locality and the period of the year from and during which the plants were collected for obtaining the glands. Drastic methods of surface sterilisation failed to remove the organism from the glands. The organism was absent in the glands of the plant raised under sterile conditions —the normal position of the same was shifted along the petiole under such conditions— but appeared on inoculation of the same with a pure culture of the organism.

The organism (Fig. 1(a) grew readily in media containing some form of combined nitrogen, inorganic and organic. In growth characteristics it was very similar to a strain of a phosphorbacterium (Fig. 1(b) obtained from Czechoslovakia. It was suspected that the two organisms must be somewhat similar, and morphological, cultural and biochemical characteristics of the organism from the Cassia glands were studied in detail and compared with those of the strain of phosphorbacterium (Fosfo 24). As these characteristics were found to be remarkably similar, solubilisation of some inorganic and organic insoluble phosphates by cultures of the two organisms was studied. Both the organisms were found to be dependent on combined nitrogen for their growth and development. The nitrogen sources in the culture media were varied to see if the nature of the nitrogenous material exerted any influence on solubilisation of phosphates.

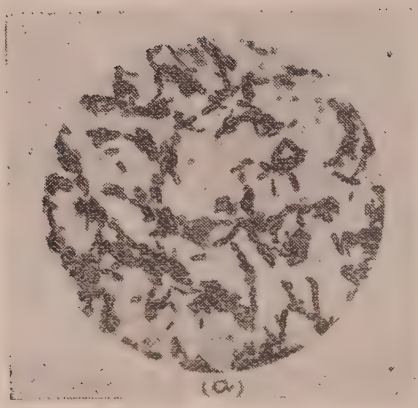

Fig. I(a)—Organism from Cassia gland

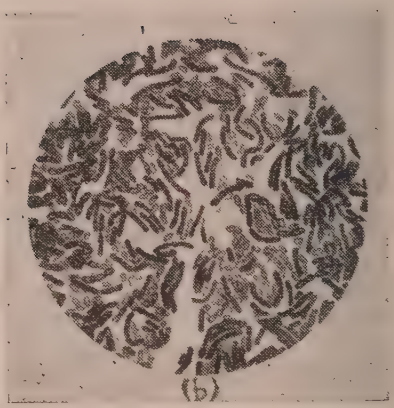

Fig. I(b)—A thick smear of Culture of phosphorbacterium (Fosfo 24)

Phosphor bacteria in the glands of *Cassia occidentalis*

This article deals with some preliminary studies on the characteristics of these two organisms and presents data on solubilisation of some inorganic and organic insoluble phosphates by the same.

Experimental procedure

Isolation of the organism. The red glands were detached from the petioles by a pair of scissors leaving small portions of the petiole attached to them. They were removed to a test tube, washed thoroughly with distilled water which was later replaced with sterile water several times. They were then steeped in mercuric chloride solution (1: 1000) for five to ten minutes. The mercuric chloride was later removed by several washings with sterile water. They were then macerated at the bottom of the test tube with a sterilised glass rod and a loopful of the suspension was plated in nutrient agar [Thornton 1922]. Single colony cultures in slants were used for studies of morphological, cultural and biochemical characteristics.

Solubilisation of phosphates. Solubilisation of the following phosphates by the culture of the organisms were determined : lecithin, calcium glycerophosphate, calcium phosphate, ferric phosphate, Trichi nodules, Singbhum phosphate and bonemeal. P_2O_5 contents of the phosphates are given in Appendix I.

The following nitrogenous compounds were used : ammonium sulphate, peptone, sodium nitrate, and urea. Nitrogen contents of the substances are given in Appendix II.

The basal medium consisted of the following : glucose—1.0 gm. ; $MgSO_4$ — ·02 gm. ; NaCl—·02 gm. ; $CaSO_4$ — ·01 gm. and distilled water — 100 c.c.; one gram of the phosphate and 0·5 gm. of the nitrogen source were added to the medium which was sterilised in flowing steam for half an hour each day for three consecutive days. They were inoculated with the organism from the glands of Cassia and the phosphorbacterium. A set without inoculation was kept as control. It was evident that as the composition of the phosphates and nitrogenous materials was different, different amounts of P_2O_5 and nitrogen were supplied in the media, by adding uniform amounts of phosphate (1 gm.) and nitrogen (0·5 gm.) sources. This was done to provide the media with an excess of the substances irrespective of the actual amounts required for the optimum growth and development of the organisms. The flasks containing the culture liquids were incubated at 30°C for a period of two months. The liquids in the culture flasks were afterwards centrifuged and the clear decants made up to a known volume with several centrifugal washings. Phosphate contents of the solutions were then determined by volumetric method of Pemberton [Wright 1934], care being taken to bind the phosphorus in the culture liquids with additions of ferric chloride before ignition of the evaporated residue to prevent loss of phosphorus by ignition. Each determination was carried out from duplicate sets for each treatment.

Results

The morphological, cultural and biochemical characteristics of the organism from the Cassia glands and phosphorbacterium (Fosfo 24) are given in Table I.

Table I

Characteristics of the organisms from Cassia glands and phosphorbacterium

Characteristics	Organism from Cassia glands	Phosphorbacterium
Morphological—	Rods, 2·7-6·7μ×1·08-1·48μ occurring in long chains, non-motile in media containing peptone but motile in media containing lecithin with peritrichous flagella, readily forms oval spores 1·3-2·1μ×0·80-·93μ, non-capsulated, gram positive, aerobic, grows well between pH 4·0-10·5 and temperature 30-36°C; minimum sporulation within 24 hours at 30°C.	Rods, 2·7-6·7μ×1·08-1·30μ occurring in long chains, non-motile in media containing peptone but highly motile in media containing lecithin with peritrichous flagella, readily forms oval spores 1·3-1·6μ×0·8-·93μ, non-capsulated, gram positive, aerobic, grows well between pH 4·0-10·5 and temperature 30-36°C; minimum sporulation within 24 hours at 36°C.
Cultural—	*Nutrient agar*—Moist, thin, cream coloured, granular colonies. *Mannite agar*—Very small round colonies, scarcely any growth. *Potato*—Heavy dry deep cream coloured wrinkled growth, starch not dextrinised.	*Nitrient agar*—Moist, thin cream coloured, granular colonies. *Mannite agar*—Very small round colonies, scarcely any growth. *Potato*—Heavy dry deep cream coloured wrinkled growth, starch not dextrinised.
Biochemical—	*Glucose*—Very slight growth, acid *Sucrose*—Very slight growth, no appreciable change in reaction. *Lactose*—No growth *Arabinose*—Very slight growth, no change in reaction. *Glycerol*—Very slight growth acid *Mannite*—Very slight growth,no change in reaction. *Dextrin*—Good growth, acid *Salicin*—Very slight growth, no change in reaction. *Dunham solution*—Heavy growth, no formation of ammonia. *Nitrate broth*—Heavy growth, no reduction. *Milk*—Curdling and acid *Litmusmilk*—Curdling and reduction. *Gelatin*—Liquefaction *Indol*—Not formed *Acetyl methyl carbinol test*—negative.	*Glucose*—Very slight growth, acid *Sucrose*—Very slight growth, no appreciable change in reaction. *Lactose*—No growth *Arabinose*—Very slight growth, no change in reaction. *Glycerol*—Very slight growth acid. *Mannite*—Very slight growth, no change in reaction. *Dextrin*—Very slight growth, acid *Salicin*—Very slight growth, no change in reaction. *Dunham solution*—Heavy growth, no formation of ammonia. *Nitrate broth*—Slight growth, no reduction. *Milk*—Curdling and acid. *Litmus milk*—Curdling and reduction. *Gelatin*—Liquefaction. *Indol*—Not formed. *Acetyl methyl carbionol test*—negative.

The average amounts of P_2O_5 that were found in water soluble form in the culture liquids without any organism and with the organism from the Cassia glands and phosphorbacterium growing in them are given in Table II.

TABLE II

Solubilisation of insoluble phosphates by the organism from the Cassia glands and phosphorbacterium

(Expressed in mg. per 100 c.c. of the media)

Phosphate	Nitrogen source	Amount of P_2O_5 in the culture liquid				
		Control	Organism from Cassia		Phosphorbacterium	
			Actual amount	Increase or decrease	Actual amount	Increase or decrease
Calcium phosphate	Ammonium sulphate	23·20	53·43	30·23	42·16	18·96
	Peptone	20·04	49·07	29·03	39·31	19·27
	Sodium nitrate	31·60	56·51	24·51	38·67	7·07
	Urea	33·19	46·39	13·20	47·17	13·98
Ferric phosphate	Ammonium sulphate	19·58	20·26	0·68	28·91	9·33
	Peptone	28·90	28·84	—0·06	42·09	13·19
	Sodium nitrate	21·70	26·67	4·97	27·18	5·48
	Urea	26·80	38·54	11·74	58·28	31·48
Calcium glycerophosphate	Ammonium sulphate	39·68	50·71	11·03	55·75	12·07
	Peptone	34·85	66·89	32·04	0·55	—34·30
	Sodium nitrate	40·92	44·44	3·52	40·69	—0·23
	Urea	18·03	59·94	41·91	56·84	38·81

TABLE II—*contd.*

Solubilisation of insoluble phosphates by the organism from the Cassia glands and phosphorbacterium

(Expressed in mg. per 100 c.c. of the media)

Phosphate	Nitrogen source	Amount of P_2O_5 in the culture liquid				
		Control	Organism from Cassia		Phosphorbacterium	
			Actual amount	Increase or decrease	Actual amount	Increase or decrease
Lecithin	Ammonium sulphate	33·12	36·06	2·94	35·72	2·60
	Peptone	42·85	38·67	—4·18	23·83	—25·02
	Sodium nitrate	31·48	43·11	11·63	10·60	—20·88
	Urea	29·62	27·13	—2·49	37·80	8·22
Trichi nodules	Ammonium sulphate	0·33	1·55	1·22	1·76	1·43
	Peptone	1·39	2·11	0·72	1·51	0·12
	Sodium nitrate	0·20	0·58	0·38	0·78	0·58
	Urea	0·07	0·51	0·44	0·59	0·52
Singbhum phosphate	Ammonium sulphate	0·33	0·58	0·25	0·66	0·33
	Peptone	2·84	7·95	5·11	2·48	0·36
	Sodium nitrate	0·15	0·54	0·39	0·16	0·01
	Urea	0·06	1·46	1·40	0·53	0·47
Bonemeal	Ammonium sulphate	2·46	37·60	35·14	37·15	34·69
	Peptone	2·29	21·25	18·96	3·70	1·41
	Sodium nitrate	0·70	2·86	2·16	3·27	2·57
	Urea	0·79	1·51	0·72	0·93	0·14

Discussion of results

It is evident from the characteristics and growth habits of the two organisms that they are almost identical with each other. Some differences exist, however, in their capacity of bringing organic and inorganic phosphates into solution in the presence of different nitrogen sources. These are apparent from the the data in Table II.

Variation in solubilisation of phosphates from calcium phosphate varies from 13·20 mg. (urea) to 30·23 mg. (ammonium sulphate) in the case of the Cassia organism ; the same in the case of the phosphorbacterium varies from 7·07 mg. sodium (nitrate) to 19·27 mg. (peptone). In the case of ferric phosphate, no solubilisation of phosphate is brought about by Cassia organism when the nitrogen source used is peptone. Otherwise the amount of phosphate solubilised varies from 0·68 mg. (ammonium sulphate) to 11·74 mg. (urea). Phosphorbacterium solubilises from 5·48 mg. (sodium nitrate) to 31·45 mg. (urea) from ferric phosphate. Similar variation in solubilisation of phosphates occurs with all other sources of phosphorous. It is clear, therefore, that solubilisation of phosphates depends to a large extent, on the nature of the nitrogen source used.

Though both the organisms showed good growth in media containing Trichi nodules and Singbhum phosphate, the amounts of phosphates solubilised are small and may be taken to be insignificant. This shows that solubilisation of phosphates depends on the nature of the phosphate as well.

There is a remarkable similarity of the amounts of phosphates dissolved as a result of growth of the two organisms in the following cases : ferric phosphates with sodium nitrate, calcium glycerophosphate with ammonium sulphate and urea, Trichi nodules with ammonium sulphate and urea, Singhbhum phosphate with ammonium sulphate, bonemeal with ammonium sulphate and lecithin with ammonium sulphate.

Both the organisms solubilise, though in different amounts, phosphates in calcium phosphate, Trichi nodules and bone meal with different nitrogen sources. There are also cases, however, where the organisms, one or the other or both show failure of solubilisation of phosphates. They have rather exhibited utilisation of whatever phosphates were already available (soluble) in the culture media. The organism from the Cassia glands fails to solubilise any phosphate from ferric phosphate and lecithin with peptone. Phosphorbacterium fails to solubilise phosphate in calcium glycerophosphate, lecithin and Singbhum phosphate with peptone and in calcium glycerophosphate, lecithin and Singhbhum phosphate with sodium nitrate.

Solubilisation of ferric phosphate in significant amounts by the organisms in presence of urea has some importance since it is in one of these forms, phosphates remain in unavailable conditions in laterite soils. High solubilisation of phosphate by the organisms in bonemeal in the presence of ammonium sulphate is also important since ammonium sulphate and urea are the commonly used nitrogenous fertilisers in soils and application of the same in the presence of the organisms in the soils is likely to bring insoluble phosphates into available conditions.

Summary

An organism has been isolated from the glands of *Cassia occidentalis* which develops freely in presence of combined nitrogen and which has got morphological cultural and biochemical characteristics identical with those of a strain of a phosphorbacterium (Fosfo 24) obtained from Czechoslovakia. The organism like the latter is an aerobic bacillus occurring as rods in long chains, forming oval spores, is gram positive and non capsulated. It is motile in media containing lecithin with peritrichous flagella but it loses its motility when grown in media containing peptone. Both the organisms bring into solution phosphorus from insoluble inorganic and organic phosphates when supplied with inorganic and organic nitrogenous substances.

Like the phosphorbacterium, quantity of phosphates brought into solution by the organism depends on the nature of the phosphate and on the nature of the combined nitrogen supplied.

In presence of commonly used nitrogenous fertilisers like ammonium sulphate and urea, the presence of the organism in the soil may increase the availability of phosphates from ferric phosphates in laterite soils and from commonly applied phosphates like bonemeal in other soils.

Acknowledgement

The strain of phosphorbacterium (Fosfo 24) from Czechoslovakia was obtained through Dr S. R. Sen of the Ministry of Agriculture. The authors thank him and also Dr B. P. Pal, Director and Dr S. P. Raychaudhuri, Head of the Division of Chemistry, Indian Agricultural Research Institute, New Delhi for permission to publish this note.

References

Menkina, R. A. (1950). Bacteria which mineralise organic phosphorus compounds. *Mikrobiologya* **19** : 308-310 ; original not seen, from *soils and Fert.*, **14** : 135, 1951

Pikovskaia, R. I. (1948). Mobilisation of phosphates in soil in connection with the vital activities of some microbial species. *Mikrobiologya* **17** : 362-370 ; original not seen, from *soils and Fert.*, **12** : 347, 1949

Thornton, H. G. (1922). On the development of a standardised agar medium for counting soil bacteria with special reference to repression of spreading colonies. *Ann. Appl. Bio.*, **9** : 241

Wright, C. H. (1934). *Soil Analysis*, p-219. Thomas Murbay and Co., London

Appendix I

Composition of the phosphatic materials

(Expressed as per cent on moisture free basis)

Phosphate	P_2O_5
Singbhum phosphate	22·33
Trichi nodule	22·72
Bonemeal	24·64
Calcium glycerophosphate	37·17
Lecithin	8·41
Ferric phosphate	47·02
Calcium phosphate	45·80

Appendix II

Composition of the nitrogenous substances

(Expressed as per cent on moisture free basis)

Substance	Nitrogen
Ammonium sulphate	20·82
Peptone	9·84
Sodium nitrate	16·15
Urea	45·43

STATISTICAL STUDIES OF THE CROP YIELD DATA

II.—STUDY OF OATS, PEAS, WHEAT AND GRAM YIELDS

(The Pusa Permanent Manurial Experiments—New Series)

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As indicated in an earlier article on the study of the maize yield data of the Pusa Permanent Manurial Experiments [Sen and Kavitkar, 1956], the rotation of crops followed was a four-year one, the *kharif* crop of maize being followed by oats, peas, wheat and gram respectively in four years in the successive *rabi* seasons. During the period of 20 years (1932-52), each of these crops, namely oats, peas, wheat and gram was grown five times. The information provided by the yields of these crops has been examined in this article with a view to studying the changes in the mean yields treatment-wise, and also to estimate the rate of deterioration due to each treatment in the yields of all the *rabi* crops. As stated earlier by Sen and Kavitkar, [1956], the experiments were laid out in ten randomized blocks with ten treatments as given below :

1. No manure (control)
2. Farmyard manure at 8000 lb. per acre = 40 lb. of N per acre (total amount applied in the last week of April or first week of May)
3. Rape cake at 40 lb. N per acre (half applied just before maize sowing and half applied at the last interculture of maize)
4. Sulphate of ammonia at 40 lb. N per acre (n)
5. Sulphate of potash at 50 lb. K_2O per acre (k)
6. Superphosphate at 80 lb. P_2O_5 per acre (p)
7. Sulphate of potash at 50 lb. K_2O + superphosphate at 80 lb. P_2O_5 per acre (pk)
8. Sulphate of ammonia at 40 lb. N + sulphate of potash at 50 lb. K_2O + superphosphate at 80 lb. P_2O_5 per acre (npk)
9. Sulphate of ammonia at 40 lb. N + superphosphate at 80 lb. P_2O_5 per acre (np)
10. Sulphate of ammonia at 40 lb. N+sulphate of potash at 50 lb. K_2O per acre (nk)

The inorganic fertilizers, alone and in various combinations, were applied half before *kharif* sowing and half before *rabi* sowing.

The net plot size was 40ft. × 20ft. (1/54·45 acre).

TABLE I

Treatment effects on oats, peas, wheat and gram (yield in maunds per acre)

Years	Treatments										S. Em	C. D. at 5 per cent	C. D. at 1 per cent	Remarks
	Control	F.Y.M.	Rape-cake	n	k	p	pk	npk	np	nk				
						Oats								
1932-33	7·51	14·38	14·85	10·06	10·06	9·55	6·80	14·92	15·55	10·00	±1·55	4·39	5·81	'F' significant at 1 per cent
1936-37	7·89	14·61	11·39	10·98	9·52	10·15	8·57	18·10	13·63	12·34	±0·69	1·94	2·57	do.
1940-41	5·13	13·75	11·28	5·72	5·58	7·62	6·40	12·03	12·78	6·25	±0·79	2·22	2·94	do.
1944-45	5·49	10·12	8·30	6·49	5·11	4·92	4·19	8·74	8·23	6·93	±0·54	1·51	2·00	do.
1948-49	5·09	10·82	7·51	7·11	6·25	6·42	6·22	8·93	10·49	8·87	±0·67	1·91	2·53	do.
Cumulative effect	6·23	12·74	10·66	8·07	7·23	7·73	6·44	12·54	12·13	8·88	±0·64	1·80	2·38	do.

TABLE I—*contd.*

Treatment effects on oats, peas, wheat and gram (yield in maunds per acre)

Year	Treatments										S. Em	C. D. at 5 per cent	C. D. at 1 per cent	Remarks
	Control	F.Y.M.	Rape-cake	n	k	p	pk	npk	np	nk				
						Peas								
1933-34	8·10	14·22	12·06	7·60	8·85	13·91	13·55	11·96	13·50	7·20	±1·03	2·91	3·86	'F' significant at 1 per cent
1937-38	1·43	2·67	2·12	1·49	1·67	2·84	2·79	3·04	3·06	1·46	±0·22	0·64	0·84	do.
1941-42	2·60	9·16	6·01	2·06	2·90	4·96	4·74	5·22	4·87	2·49	±0·68	1·90	2·51	do.
1945-46	2·01	5·31	4·65	2·30	2·83	3·59	3·22	3·81	4·38	2·31	±0·39	1·10	1·47	do.
1949-50	1·47	3·29	2·48	1·59	1·55	2·10	1·89	2·54	2·58	1·39	±0·26	0·75	0·99	do.
Cumulative effect	3·12	6·93	5·46	3·01	3·56	5·48	5·23	5·31	5·68	2·97	±0·42	1·19	1·58	do.

TABLE I—*contd.*

Treatment effects on oats, peas, wheat and gram (yield in maunds per acre)

Years	Treatments										S. Em	C. D. at 5 per cent	C. D. at 1 per cent	Remarks
	Control	F.Y.M.	Rape-cake	n	k	p	pk	npk	np	nk				
						Wheat								
1934-35	5·54	10·57	8·21	6·44	5·99	6·75	5·30	9·69	9·01	7·05	±0·56	1·59	2·11	'F' signl-ficant at 1 per cent
1938-39	3·13	5·21	4·10	4·27	3·71	2·79	2·43	4·68	5·14	4·74	±0·38	1·06	1·40	do.
1942-43	4·12	8·58	6·55	5·99	3·72	4·13	4·08	7·93	7·23	5·71	±0·45	1·27	1·68	do.
1946-47	5·15	8·44	8·52	7·81	4·98	5·64	4·47	8·56	9·28	7·97	±0·44	1·23	1·63	do.
1950-51	3·08	4·33	3·96	5·63	3·55	3·47	2·74	4·82	6·57	5·07	±0·44	1·23	1·63	do.
Cumulative effects	4·20	7·42	6·27	6·03	4·39	4·56	3·80	7·13	7·44	6·11	±0·28	0·78	1·04	do.

TABLE I—*contd.*

Treatment effects on oats, peas, wheat and gram (yield in maunds per acre)

Years	Treatments										S. Em	C. D. at 5 per cent	C. D. at 1 per cent	Remarks
	Control	F.Y.M.	Rape-cake	n	k	p	pk	npk	np	nk				
						Gram								
1935-36	9·25	16·28	13·03	8·58	8·42	14·32	12·68	13·83	14·44	8·11	±1·07	3·00	3·98	'F' significant at 1 per cent
1939-40	9·02	11·15	10·22	7·09	7·04	12·76	12·74	9·98	11·78	7·15	±0·81	2·30	3·04	do.
1943-44	0·87	1·61	1·36	0·60	0·80	1·00	0·77	0·83	0·65	0·77	±0·17	0·47	0·62	do.
1947-48	4·56	7·30	6·48	3·43	4·40	6·47	4·35	5·15	6·50	4·21	±0·54	1·50	1·99	do.
1951-52	3·97	6·99	4·29	2·75	2·86	3·35	1·73	2·75	3·29	2·41	±0·56	1·56	2·07	do.
Cumulative effects	5·53	8·67	7·08	4·49	4·70	7·58	6·46	6·51	7·33	4·53	±0·39	1·09	1·44	do.

TABLE II

Main effects and interactions of nitrogen (N), phosphorus (P) and potash (K) on oats, peas, wheat and gram in maunds per acre

Years	N	P	NP	K	NK	PK	NPK	S.E.
				Oats				
1932-33	+4·15**	+2·30*	+2·91**	—0·22	—0·13	—1·47	+1·18	±1·10
1936-37	+4·73**	+2·43**	+1·78**	+1·47**	+1·45**	—0·03	+1·58**	±0·49
1940-41	+3·01**	+4·03**	+2·38**	—0·24	+0·13	—0·74	+0·10	±0·56
1944-45	+2·69**	+0·54	+1·24**	—0·07	+0·54	—0·05	+0·08	±0·38
1948-49	+2·85**	+1·18*	+0·54	+0·29	—0·19	—1·17*	—0·49	±0·48
Average response	+3·49**	+2·10**	+1·77**	+0·24	+0·36	—0·69	+0·49	±0·45
				Peas				
1933-34	—1·04	+5·29**	+0·04	—0·39	—0·58	—0·56	—0·01	±0·73
1937-38	+0·08	+1·42**	+0·16	+0·04	—0·06	—0·08	+0·08	±0·16
1941-42	—0·14	+2·43**	+0·34	+0·21	+0·18	—0·15	+0·12	±0·48
1945-46	+0·29	+1·39**	+0·40	—0·03	—0·25	—0·44	+0·16	+0·28
1949-50	+0·28	+0·78**	+0·29	—0·10	—0·03	—0·04	+0·12	±0·19
Average response	—0·11	+2·26**	+0·25	—0·06	—0·15	—0·25	+0·09	±0·30

*Significant at 5 per cent
**Significant at 1 per cent

TABLE II—*contd.*

Main effects and interactions of nitrogen (N), phosphorus (P) and potash (K) on oats peas, wheat and gram in maunds per acre

Years	N	P	NP	K	NK	PK	NPK	S.E.
				Wheat				
1934-35	+2·15**	+1·43**	+1·17**	+0·07	+0·57	—0·46	+0·49	±0·40
1938-39	+1·70**	—0·20	+0·61*	+0·06	—0·05	—0·47	+0·001	±0·27
1942-43	+2·70**	+0·96**	+0·77*	—0·01	+0·21	+0·33	0·16	±0·32
1946-47	+3·34**	+0·51	+0·52	—0·48	+0·20	—0·47	+0·05	±0·31
1950-51	+2·31**	+0·07	+0·28	—0·65*	—0·51	—0·60	+0·002	±0·31
Average response	+2·44**	+0·55**	+0·67**	—0·20	+0·08	—0·33	+0·14	±0·20
				Gram				
1935-36	+0·07	+5·23**	+0·56	—0·89	+0·35	—0·24	+0·17	±0·75
1939-40	—1·39*	+4·24**	—0·48	—0·93	+0·07	+0·03	—0·95	±0·58
1943-44	—0·15	+0·05	+0·001	+0·01	+0·16	—0·03	+0·05	±0·12
1947-48	—0·13	+1·47**	+0·54	—0·71	+0·43	—1·02**	—0·04	±0·38
1951-52	—0·18	—0·22	+0·66	—0·90*	+0·46	—0·18	+0·07	±0·39
Average response	—0·35	+2·15**	+0·25	—0·68*	+0·29	—0·29	—0·14	±0·27

*Significant at 5 per cent
**Significant at 1 per cent

1. *Testing of treatment effects in individual years*

The yield data of oats, peas, wheat and gram were statistically analysed [Fisher, 1941] year by year, in the first instance, to study the performance of the different treatments; the statistical analysis indicated significant differences among the treatments. The results of the statistical analysis are summarised in Tables I and II.

2. *Cumulative effects of the treatments*

The plot yields of oats, peas, wheat and gram for each treatment for five years were added up and the totals were statistically analysed separately for each crop to see the average effect of the treatments on the various crops. The statistical analysis indicated highly significant differences among the treatments under each crop. The results of the statistical analysis are incorporated in Tables I and II.

3. *Regression of yield on years*

Linear regression of yield on years, representing the deterioration was worked out plot-wise for oats, peas, wheat and gram. Average regression for each treatment was then computed from these values. These average regressions were then tested for significance by analysis of variance method [Cochran, 1939]. The method is illustrated in Table III.

TABLE III

Analysis of variance for testing linear regression coefficients

Source	Degrees of freedom	Sum of squares
1. Blocks	9	$\sum_{1}^{10}(\sum_{1}^{10} b\ \Sigma\xi,y)^2/(\Sigma\xi^2)^2 x10$—C.F.
2. Treatment regressions	9	$\sum_{1}^{10}(\sum_{1}^{10} t\ \Sigma\xi y)^2/(\Sigma\xi^2)^2 x\ 10$—C.F.
3. Error	81	(4)—(2+1)
4. Total	99	$\sum_{1}^{100}(\Sigma\xi y)^2/(\Sigma\xi^2)^2$—C.F.

where $\sum_{1}^{10} b\ \Sigma\xi y$ = Total $\Sigma\xi y$ for blocks over 10 treatments

$\sum_{1}^{10} t\ \Sigma\xi y$ = Total $\Sigma\xi y$ for treatments over 10 replications

C. F. (Correction Factor) $= [\sum_{1}^{100} \Sigma\xi y]^2/(\Sigma\xi^2)^2 x100$

The method provides valid comparisons between the regression coefficients and it is also useful in identifying the groups of treatments which have similar trends.

The test indicated significant differences between the regression terms for different treatments under each crop. The results are summarised in Tables IV and V.

TABLE IV

Linear regression coefficients (in maunds per acre) treatment-wise for oats, peas, wheat, and gram

Treatments	Regression coefficients			
	Oats	Peas	Wheat	Gram
Control	—0·72	—1·27	—0·28	—1·50
Farmyard manure	—1·16	—1·92	—0·93	—2·24
Rape-cake	—1·78	—1·66	—0·41	—2·12
n	—1·04	—1·12	+0·19	—1·53
k	—1·21	—1·34	—0·36	—1·38
p	—1·15	—2·28	—0·37	—2·83
pk	—0·56	—2·29	—0·30	—3·03
npk	—2·14	—1·81	—0·59	—2·70
np	—1·55	—2·05	—0·07	—2·76
nk	—0·77	—1·08	—0·07	—1·44
S. E.	±0·35	±0·18	±0·16	±0·35
C. D. at 5 per cent	0·97	0·52	0·46	0·99
C. D. at 1 per cent	—	0·69	0·61	1·32
'F'	Significant at 5 per cent only	Significant at 1 per cent	Significant at 1 per cent	Significant at 1 per cent

TABLE V

Linear regression coefficients for main effects and interactions of nitrogen(N), phosphorus (P) and potash (K) (in maunds per acre) for oats, peas, wheat and gram

Effects	Regression coefficients			
	Oats	Peas	Wheat	Gram
N	—0·46	+0·28*	+0·20	—0·08
P	—0·42	—0·90**	—0·20	—1·36**
NP	—0·52*	+0·08	—0·18	—0·04
K	—0·06	+0·06	—0·20	+0·02
NK	—0·10	+0·10	—0·20	—0·10
PK	—0·06	+0·06	—0·02	—0·08
NPK	—0·48*	+0·04	—0·10	—0·10
S. E.	±0·24	±0·14	±0·12	±0·26

*Significant at 5 per cent **Significant at 1 per cent

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4. *Percentage rate of deterioration in yield of different crops*

In order to obtain an idea of the relative rate of deterioration in the *kharif* crop maize and the *rabi* crops, oats, peas, wheat and gram under the various treatments, the average linear regression coefficient for a given treatment for each crop has been expressed as a percentage of the average yield of the crop for the treatment. These percentages are given in Table VI.

TABLE VI

Percentage rate of deterioration in yield of maize, oats, peas, wheat and gram

Treatments	Maize	Oats	Peas	Wheat	Gram
Control	8·08	11·58	40·68	6·77	27·15
Farmyard manure	5·54	9·14	27·67	12·48	25·86
Rape-cake	6·82	16·69	30·39	6·55	29·91
n	6·10	12·86	37·14	3·18	34·17
k	7·60	16·62	37·73	8·28	29·25
p	7·74	14·90	41·62	8·13	37·26
pk	7·28	8·63	43·74	8·00	46·93
npk	6·76	17·04	34·00	8·26	41·46
np	7·00	12·81	36·13	0·98	37·64
nk	6·14	8·64	36·30	1·19	31·68

DISCUSSION

An examination of the yield data (Table I) of oats, peas, wheat and gram for the individual years under various treatments indicated highly significant differences amongst them. Even in the year 1943-44 when the gram crop failed due to bad season, the treatment differences were found to be significant. All the *rabi* crops showed a good response to farmyard manure, but the response to rape cake was not as good as was noticed in the case of *kharif* crop, maize [Sen and Kavitkar, 1956]. This may be due to more readily available nitrogen in rape cake than that in farmyard manure. The treatment 'np' had also shown favourable effect on all the crops, but the complete fertilizer treatment 'npk' was more effective than 'np' only on oats. Superphosphate 'p' alone had a good effect on peas and gram showing thereby the beneficial effect of phosphate on legumes. Ammonium sulphate 'n' alone, on the contrary, did not fare well with these crops. Sulphate of potash 'k' and its combinations were not effective as they did not give better response than the control in most of the cases.

The study of the main effects and interactions of nitrogen (N), phosphorus (P) and potash (K) (Table II) revealed that N had highly significant and positive effect on the cereal crops of oats, and wheat, but the legumes, namely peas and gram did not react well with it. Phosphorus (P) and NP showed significant effects on oats and wheat in some cases, but the legumes peas and gram showed a good response to P alone. None of the crops, however, gave favourable response to K.

Cumulative effect of treatments

The results of the statistical analysis of the total yields over five years under each crop (Table I) relating to the performance of the different treatments showed the same trend as found earlier by the study of the effect of different treatments in individual years. Farmyard manure, on an average gave highest yields of oats, peas and gram, but ammonium sulphate with super phosphate 'np', though in general found effective on all the crops, showed highest yields of wheat only. Farmyard manure established its superiority over rape cake under all the *rabi* crops. The response to farmyard manure, as reflected by the yields of *rabi* crops, was better than that shown by the *kharif* crop, namely maize [Sen and Kavitkar, 1956]. This may be due to the fact that the nutrients in farmyard manure which was applied before *kharif* sowing were not fully available to maize and by the time *rabi* crops were sown, the manure became effective.

The response to the complete fertilizer treatment 'npk' was also remarkable under oats and wheat crops only. Superphosphate 'p' was, however, found much more beneficial to peas and gram, but sulphate of potash 'k' alone and in combination with ammonium sulphate 'n' and superphosphate 'p' respectively did not prove effective on any of the crops. It is, therefore, evident that the cereal crops like oats and wheat require nitrogen, while the legumes like peas and gram need phosphate manuring to show beneficial results.

The study of the main effects and interactions of nitrogen (N), phosphorus (P) and potash (K) (Table II) also supports the above findings. Thus the main response to N was significant and positive for oats and wheat and negative, though non-significant, for peas and gram. The interaction NP was positive for all the crops, but it was significant only for oats and wheat. All the crops, however, responded to P, the response being high in the case of peas and gram. Potash (K) and interactions PK, NK and NPK did not show favourable effects on any of the crops.

Regression of yield on years

The regression coefficients (Table IV) were significant for all the treatments under oats, peas and gram. Under wheat, the treatments farmyard manure, rape cake, k, p and npk only indicated significant regression coefficients.

The study of linear regression for the treatments under each crop points out, therefore, that the rate of deterioration was predominant with all the treatments applied to peas, gram and oats and only five treatments indicated significant deterioration in wheat yields.

Comparison of regression coefficients

All the ten treatments in general indicated deterioration in yields of all the four crops (Table IV). The treatments superphosphate 'p' alone and in combination with sulphate of potash 'pk' showed the highest rate of deterioration in peas and gram yields. It is worth noting that although superphosphate 'p' raised the yields of peas and gram, it also showed the highest rate of deterioration among the

fertilizer treatments. The complete fertilizer treatment 'npk' indicated the maximum rate of deterioration under oats, and farmyard manure gave the highest rate of deterioration in wheat yields. These treatments also raised the yields of oats and wheat.

The values of regression coefficients for main effects and interactions of nitrogen, phosphorus and potash (Table V) support the finding stated above.

Percentage rate of deterioration in yields

The percentage rates of deterioration as given in Table VI for all the treatments under the crops viz. maize, oats, peas, wheat and gram vary from crop to crop and treatment to treatment. In general, the treatments which gave higher yields registered high percentage rate of deterioration. The complete fertilizer treatment 'npk' effected increases in yield of oats and also gave high percentage rate of deterioration. Similarly, superphosphate 'p' raised the yields of peas and gram and also effected high percentage rate of deterioration. Although farmyard manure established high yields of wheat and showed maximum percentage rate of deterioration, it indicated comparatively low percentage rate of deterioration in maize, peas and gram yields.

Summary

In the Permanent Manurial Experiments (new series), conducted at Pusa, the *kharif* crop maize was succeeded by oats, peas, wheat and gram respectively in succession in the *rabi* season in four years. Each of these crops was grown five times in a period of 20 years. The yields of these crops were examined statistically in detail to study the changes in the mean yields year after year treatment-wise and to determine the rate of deterioration in yields.

1. All the *rabi* crops gave a good response to farmyard manure as compared to rape cake.

2. Superphosphate had beneficial effect on the yield of peas and gram.

3. The oat and wheat crops showed a good response to nitrogen (N) and peas and gram to phosphorus (P).

4. Superphosphate alone and in combination with sulphate of potash gave significantly the highest rate of deterioration for peas and gram.

5. Farmyard manure indicated comparatively low percentage rate of deterioration in the yield of maize, peas and gram.

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References

Cochran, W. G. (1939). Long-term agricultural experiments. *J. Roy. Stat. Soc. Suppl.* **6** : 104-148

Fisher, R. A. (1941). *Statistical methods for research workers*, Edinburgh

Sen, S. and Kavitkar, A. G. (1956). Statistical Studies of the Crop Yield Data of the Pusa Permanent Manurial Experiments—New Series I. Study of Maize Yields. *Indian J. agric. Sci.* **26**(1) 105-129.

THE EFFECT OF THE PRESENCE AND ABSENCE OF PHOSPHORUS AT DIFFERENT PERIODS OF GROWTH OF *VICIA FABA*

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(with two Text-Figures)

THE realisation of the importance of the mineral elements in plant nutrition has led to a great deal of attention being concentrated on the phases of the life history of the plant when the need for the element is greatest. The subject is of vital significance from the commercial point of view of crop production, and has received considerable attention experimentally ; now there is an agreement between all the workers that it is desirable to have a large amount of the nutrient elements in the soil solution at the commencement of the plant's growth cycle, but it may be unnecessary, and even undesirable to maintain this condition during later stages of growth.

Gericke [1924, 1925] found that the removal of wheat plants grown for 4 weeks in a complete nutrient solution to a potassium-free medium resulted in a production of dry matter equal to that obtained from cultures grown in a complete nutrient solution. The maximum development among all cultures was obtained from the plants grown 4 weeks in a complete nutrient solution and then transferred into a solution lacking phosphorus. Decrease occurred in the ultimate dry-weights as the initial period with phosphorus was lengthened. The plants receiving phosphorus throughout the experimental period were amongst those with the lowest dry-weight.

Brenchley [1929] tested the phosphate requirements of barley at different periods of growth. She found that the importance of phosphorus is in the first few weeks of plant life, the whole course of the life history being influenced by the conditions at this stage far more than by changes at later stages. There was a decrease in dry weight with continuous supply of phosphorus. Miller [1938] gave excellent reviews of the literature the mineral requirements for the growth of higher plants at different stages of growth.

In Egypt, much attention has been given to the phosphate fertilization problem of soils. Easily soluble phosphates when added to the soil are rapidly converted into insoluble form, and that only a small proportion of the added phosphate is taken up by the crop, the rest converted to useless or almost useless forms. Accordingly, it is of vital importance to provide the growing plant with soluble phosphates at the proper stage so as to enable them to make full use of the available phosphates present, before they are locked up in the soil.

Hence, the purpose of the sand-culture experiment to be described here has been to investigate whether phosphorus requirements for healthy growth and development of *Vicia faba* plants are more critical at any stage of growth than any other element. It is to be stated here that this plant differs from cereals in that the latter complete their growth soon after heading, while in the former flowering is prolonged, and the plant has a more or less continuous development. *Vicia faba* is one of the most economically important crops in Egypt.

Material and Methods

The seeds of *Vicia faba* (Var. Ribaya 34) were sown in pots of sand-cultures. The pots were of glazed earthenwares 7·5 in. in diameter and 9 in. deep. They were provided below with a side tube closed with a cork stopper connected to a right angled glass tube. This tube allowed percolation of excess culture-solutions. Sand after having been sieved on 24 mesh sieve, was saturated with a 3 per cent hydrochloric acid. The saturated sand was left in contact with the acid for a week, then washed with a rapid stream of water for 72 hours. It was further washed with water for three days (once every 24 hours). The sand was then leached with phosphorus-free culture solution twice daily until the leachate had the same *p*H value as that of the nutrient solution and showed no change after remaining in contact with sand for 24 hours.

The nutrient solution used in this experiment was similar to that described and used by Hewitt [1945] at Long Ashton Research Station, Bristol University, England. The composition of the standard complete nutrient solution was as follows :

Salt	Wt. in gm. [for 20 litres of diluted nutrient]
$Ca(NO_3)2$	10·92
KNO_3	6·66
$Na\ H_2\ PO_4 . 2H_2O$	4·16
$Mg\ SO_4 . 7\ H_2O$	7·36
$Fe\ (C_6H_5O_7) . \ 3H_2O$	0·49
$H\ BO_3$	0·0372
$Mn\ SO_4 . 4\ H_2O$	0·0446
$Cu\ SO_4 . \ 5\ H_2O$	0·0050
$Zn\ SO_4 . \ 7H_2O$	0·0054
$(NH_4)_6\ MO_7\ O_{24} . 4\ H_2O$	0·0007

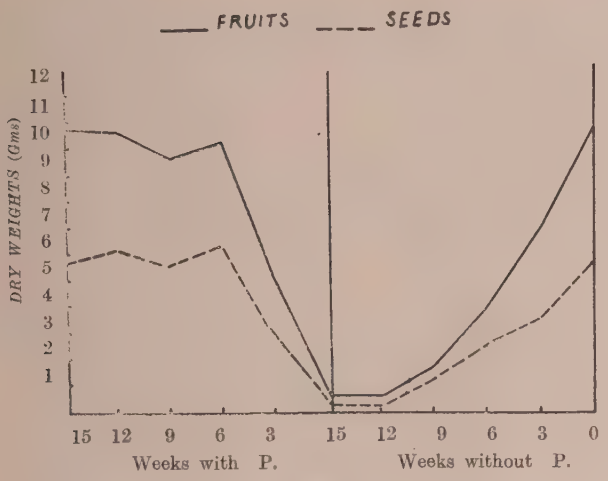
FRUITS
SEEDS
DRY WEIGHTS (Gms)
12
11
10
9
8
7
6
5
4
3
2
1
15 12 9 6 3 15 12 9 6 3 0
Weeks with P.
Weeks without P.

FIG. 1

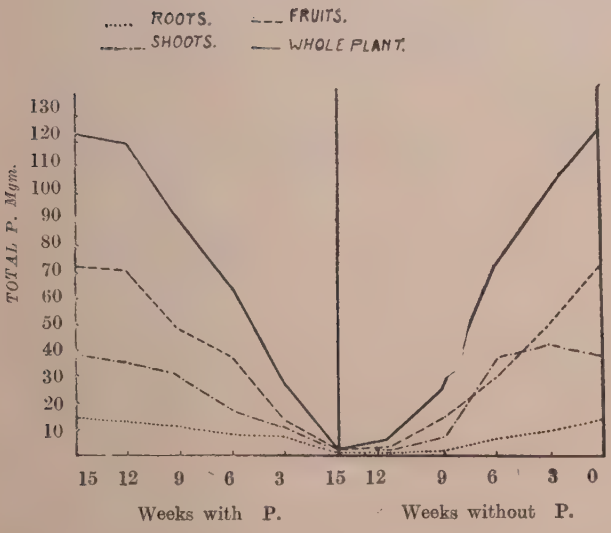
ROOTS.
SHOOTS.
FRUITS.
WHOLE PLANT.
TOTAL P. Mgm.
130
120
110
100
90
80
70
60
50
40
30
20
10
15 12 9 6 3 15 12 9 6 3 0
Weeks with P.
Weeks without P.

FIG. 2

The solution lacking phosphorus was prepared with an equivalent amount of sodium sulphate to substitute the sodium phosphate. The solution was added during intervals of 3 or 4 days in amounts sufficient to leach through the pot. When necessary, tap-water was added between the nutrient applications. The *p*H value of the nutrient solution varied between 6·0 to 6·3. Before changing the treatment during the growth of the plants (from + to — P and *vice versa*), the sand was leached with three successive portions of one litre of water followed by one litre of the new nutrient solution.

The pots were grown in the open air and were arranged in double rows on benches about 20 in. above the ground.

Plan of the experiment

The general plan of the experiment was to supply plants for varying periods with complete nutrient solutions containing phosphorus, and then to supply them with solutions devoid of this element, and allowed to complete their growth. Likewise, plants were started with nutrient solutions lacking phosphorus, allowed to grow to varying lengths of time, and then they were supplied with nutrient solutions containing phosphorus. The successive transfers of plants were made at 3 week intervals. This gave the setting of two series of plant sets, grown respectively with and without phosphorus for different stages of growth. At the close of the experiment, each set consisted of four plants.

The general plan of the experiment is shown in Table I.

TABLE I

The general plan of the experiment showing the various periods of presence and absence of phosphorus in the nutrient solution

Treatment designation	1st period (3 weeks)	2nd period (3 weeks)	3rd period (3 weeks)	4th period (3 weeks)	5th period (3 weeks)
A	+ P	— P	— P	— P	— P
B	+ P	+ P	— P	— P	— P
C	+ P	+ P	+ P	— P	— P
D	+ P	+ P	+ P	+ P	— P
E	+ P	+ P	+ P	+ P	+ P
F	— P	+ P	+ P	+ P	+ P
G	— P	— P	+ P	+ P	+ P
H	— P	— P	— P	+ P	+ P
I	— P	— P	— P	— P	+ P
J	— P	— P	— P	— P	— P

Five seeds were sown directly in the sand on November 11th, 1954. Germination began on November 24th and was practically complete on November 29 [germinative capacity 100 per cent]. Thinning to two plants per pot was made on November 30. The differential treatments started on December 6, three weeks after sowing.

Weekly observations of plant colour, leaf and branch production, and fruiting were regularly obtained throughout the whole period of the experiment on all pots. At the close of the experiment, the pots were removed and the soil was washed away from the roots by a stream of water. The dry weights of roots, tops, fruits and seeds were then determined separately. Number of fruits per plant and seeds per fruit were also determined. The dry matter of roots, shoots and fruits were subsequently ground separately and stored for phosphorus determination.

Phosphorus in the dry tissues of roots, tops and fruits of the plants of the various treatments was estimated colorimetrically. The molybdenum blue method described by King [1951] was adopted for estimating phosphorus.

Results and Discussion

Observations during growth

During the first fortnight of treatment, all plants, either receiving phosphorus or not, were very uniform in behaviour. They were much similar in size, height and number of leaves. The normal growth of cultures deprived of phosphorus during this period seems to be at the expense of the phosphorus in the seeds. In this connection, Maximov [1938], studying the composition of ash of the vegetative organs and seeds of some important agricultural plants, has recorded that seeds of beans are rich in phosphorus and potassium, elements necessary for the building up of new organs. Chemical analysis of the seeds used in this experiment has shown that the phosphorus content is 3·929 mgm. per gram dry weight of such seeds.

Those plants which were supplied with phosphorus during the first period (three weeks) and then deprived of phosphorus continued to grow as rapidly as the control of this series (treatment E). After six weeks of omission of phosphorus, the rate of growth began to fall off. One week later, the characteristic symptoms of phosphorus deficiency started to take place in the lower leaves of the plant. Such leaves became pale in colour and chlorotic. The chlorosis was confined to the areas between the veins, the veins themselves being usually green. Later on, the edges of the lower leaves were scorched and the whole leaf gradually perished. At this stage, the plants ceased to produce new leaves and the growth mainly confined to the developing fruits which ripened relatively early. It appears, therefore, that the growth of those plants was merely at the expense of the amount of phosphorus derived from the nutrient solution, during the first three weeks, when phosphorus was available. This amount absorbed was not sufficient to maintain a normal metabolic process during the later periods of growth.

Provided phosphorus was available for the first six weeks in treatment, its absence at any later date did not affect the growth and development of the plants. Those plants of treatments B, C, D, and E which were respectively supplied with phosphorus for 6, 9, 12 and 15 weeks were similar in type, healthy and did not exhibit any symptoms of malnutrition throughout the whole period of the experiment.

Omission of phosphorus during the first period only (treatment F) resulted in the appearance of early symptoms of phosphorus deficiency. Such symptoms were confined to the development of slight chlorosis on the lower leaves, especially their edges. The growth was decreased and the newly developed leaves were markedly reduced in size. Three days after having received plus-phosphorus nutrient solution, these cultures gave evidence of rapid recovery. The first response was shown in the growing points as the plants renewed their active growth and produced green, healthy leaves. There was a noticeable increase in the size of the newly developed leaves. In all instances, the lower fully developed leaves, which had been showing phosphorus deficiency symptoms at the time of changing the treatment, never recovered, but the symptoms came to a standstill and did not progress any further. Despite the renewal of healthy growth in these cultures after treatment with phosphorus, the size of such plants at the close of the experiment was markedly less than that of controls (treatment E).

As the period of initial deprivation of phosphorus was increased to 6 weeks (treatment G), the later stages of phosphorus deficiency symptoms consisted largely of a progressive increase in the severity of the earliest symptoms shown on the plants, especially in the leaves. The lower leaves became entirely yellow. Moreover, their edges were scorched and they soon withered and shrivelled up. Dying back started from the lowest leaf on the stem. This was accompanied by a marked decrease in the rate of growth of the plants. The newly developed leaves were much reduced in size and light green in colour. When these plants were supplied with phosphorus, the recovery started within four days. The terminal buds regained their active growth, and newly developed leaves were normal in size, colour and general appearance. The recovery however, was not as active and rapid as in cultures of treatment F. At the time of harvesting, the lower leaves of those plants still exhibited the characteristic phosphorus deficiency symptoms.

When phosphorus was withheld for 9 weeks (treatment H) the nature of the plant was changed completely. The growth was severely checked and the main shoot turned thin. The leaves were extremely small in size and quite pale. Rapid death of lower leaves became more pronounced. Five days after changing the treatment from minus to plus-phosphorus, these cultures showed signs of recovery. The plants renewed their growth and produced green healthy leaves. In spite of this recovery, such cultures, at the time of harvesting, were inferior in all respects.

As the period of initial phosphorus deprivation was increased to more than 9 weeks (treatments I and J), the growth of the whole plant practically came to a standstill. All the leaves of the plants in those two treatments had died with the exception of few yellow, pale leaves, crowded around the terminal buds. When cultures of treatment I were supplied with phosphorus, they did not show any

response to phosphorus treatment. It seems more likely that those cultures, with longer period of initial phosphorus deprivation, lost the capacity to grow any more, even when supply of phosphorus became available later.

It is evident from the above observations that the presence or absence of phosphorus during the early stages of growth is of most vital importance. The critical period for the necessity of phosphorus seems to lie between the fourth and ninth week after sowing. When sufficient amount of this element is present in the medium during such period, growth proceeds normally as well and nearly to the same degree as though phosphorus is present throughout. At the same time the absence of phosphorus during the critical period has a definite influence on the later development of the plant. With longer periods of phosphorus deprivation, growth is steadily depressed.

Dry weights

Average dry weights of roots and shoots of plants of each treatment are shown in Table II.

TABLE II

Average dry weights of roots, shoots and whole plant as well as root ratio for the plants of the various treatments

Treatment designation	Weeks with or without phosphorus	Average D. W. (gm.)			Shoot/root ratio
		Ratio	Sheets	Entire plant	
A	+ 3	4·13	9·87	14·00	2·39
B	+ 6	4·65	14·86	19·51	3·19
C	+ 9	5·07	15·96	21·03	3·14
D	+12	4·34	15·15	19·49	3·49
E	+15	4·87	16·45	21·32	3·38
F	— 3	3·73	13·00	16·73	3·48
G	— 6	1·69	7·61	9·20	4·44
H	— 9	0·98	2·43	3·41	2·48
I	—12	1·28	1·69	2·97	1·32
J	—15	1·10	1·66	2·76	1·50
S. E. of treatment meas		0·6	0·76	1·05	

It is quite evident that the dry weight per plant was not significantly affected, provided phosphorus was available in the medium during the first six weeks or longer. Shorter treatment with phosphorus (treatment A) caused considerable decrease in the dry weight of the plant. Longer treatment with phosphorus for more than six weeks (treatments C, D and E) had no significant influence on the growth and development of the whole plant.

The omission of phosphorus for the first period of the experiment (treatment F) had a significant effect on the dry matter production of the plants, if compared with those receiving phosphorus throughout. Deprivation for 6 weeks (treatment G) caused a sharp decrease in the dry weights of both roots and shoots. As the period of initial omission increased (treatments H, I and J), the dry matter continued to decrease.

The values involving the shoot/root/ratios in dry weights of the plants of the various treatments are also given in Table II. As regards plants initially supplied with phosphorus, no differences could be detected in the relative weight of tops and roots of plants of treatments B and C. There was a slight increase in such values in plants of treatments D and E. On the other hand, treatment A showed a relatively lower value indicating that the tops were affected more relatively than the roots as the result of phosphorus deficiency.

Cultures initially deprived of phosphorus varied greatly in such values. Treatments F and G showed higher values while those suffering from serious phosphorus deficiency (treatments H, I and J) gave lower values. It is clear that in treatment G, the dry matter production of shoots were much higher in proportion than that of roots as a result of such phosphorus treatment and consequently the ratio was the highest in the present experiment.

It thus can be safely concluded that the dry matter of shoots generally decreases in response to phosphorus deficiency more than does the dry matter of their roots, resulting in lower values of shoot/root ratios.

From the foregoing results it is clear that cultures supplied with phosphorus during the first two periods of the experiment were not significantly different from those receiving phosphorus throughout. On the other hand, the absence of this element during the same two periods has a drastic effect on the growth and development of the plants. The decrease of both roots' and tops' dry weights was sharp, the difference between these cultures and those receiving phosphorus during the same critical period was very great. These results clearly show that, under the conditions of the present experiment, the importance of phosphorus lies in the first six weeks after the complete germination of the seeds. The presence of phosphorus during that period in the medium permits the plants to grow normally.

These conclusions are quite in accordance with the investigations of Brenchley [1929] on barley which indicated that the critical period of phosphate need for vegetative growth seemed to lie between the first four and six weeks.

Fruit yield

Plants of all treatments produced fertile blossoms which set fruits freely. Fruits of all treatments developed more or less normally until they acquired a size of 2 cm. in length. From this stage of fruit development onwards, fruits of the various treatments differed markedly in their rate of growth.

Omission of phosphorus after 3 weeks of initial supply (treatment A) had a drastic effect on fruit production. The fruits were comparatively reduced in size and dry weight. The course of events for the average number of seeds per fruit and their individual dry weight was similar to the above (Table III).

TABLE III

Average fruit and seed yields

Treatment designation	Weeks with or without phosphorus	D. W. of fruits per plant (gm.)	D. W. of seeds per plant (gm.)	No. of fruits per plant	D. W. per fruit	No. of seeds per plant	D. W. per seed
A	+ 3	5·14	2·94	5·5	0·92	12·7	0·24
B	+ 6	10·31	6·33	7·17	1·44	18·0	0·35
C	+ 9	9·74	5·70	7·8	1·25	22·8	0·25
D	+12	10·63	6·23	8·3	1·28	22·8	0·27
E	+15	10·67	5·80	9·5	1·12	23·2	0·25
F	— 3	7·02	3·63	6·0	1·17	17·5	0·21
G	— 6	4·13	2·68	4·5	0·92	10·0	0·27
H	— 9	1·98	1·28	2·5	0·79	5·0	0·26
I	—12	7·70	0·38	1·0	0·70	1·3	0·29
J	—15	0·69	0·40	1·0	0·69	1·3	0·26
S. E. of treatment means		0·81	0·67				

Plants under treatment B, supplied with phosphorus for the first two periods were able to develop the most perfect and vigorous fruits and seeds in this experiment. As regards the total dry weights of fruits and seeds per plant, they can be compared favourably with those produced by plants receiving phosphorus throughout their growth.

As the period of initial phosphorus supply was lengthened to more than 6 weeks (treatments C, D and E), the effect of phosphorus was seen in the increased number of both fruits and seeds per plant; there was no effect on their total dry weights per plant. The average size and weight of such fruits and seeds were more reduced than those of treatment B. This was also accompanied by a delay in the ripening of such fruits.

The absence of phosphorus during the first period (treatment F) has a marked influence on the later production of fruits and seeds. When initial phosphorus starvation was increased to six weeks (treatment G), there was a sharp decrease in both fruit and seed yields, paralleling closely its effect on dry matter production of the plants. As the period of deprivation increased, fruit and seed yield continued to decrease very sharply [treatments H, I and J]. It is also evident, (Fig.1), that plants of treatments F, G and H, initially deprived of phosphorus, seemed to exhibit a proportional response, in fruit and seed yield, to the length of period in which phosphorus was present in the substrate. Cultures supplied with phosphorus after 12 weeks of phosphorus deprivation did not respond to such treatment.

One of the outstanding features of the results of the present experiment was that plant grown without phosphorus (treatment J) reached a point where the capacity of the plant was directed to the formation of small fruit at the expense of the phosphorus stored in the seed.

It is evident then, that the critical period of phosphorus held for fruit and seed production is at the beginning of development, this being marked during the first six weeks of the life of the plant. Similar results were obtained by Brenchley [1929] on barley plants. It was stated that the necessity of phosphorus for proper grain formation was most between the second and fourth week and fully supplied by the sixth.

Phosphorus content of plant tissues

(a) Phosphorus present at beginning :

Very little phosphorus was absorbed when phosphorus was only present during the first period (treatment A). The relatively delayed appearance of deficiency symptoms after changing from a plus-phosphorus solution to a minus-phosphorus nutrition, suggests that there was utilization and transfer of reserve phosphorus absorbed during that period. This amount of phosphorus was not sufficient to fulfill the requirements of the plant during later stages of growth. With longer period of initial supply the uptake increased rapidly as indicated by the increased phosphorus concentration within the tissues of roots, shoots and fruits. This is clearly shown in Table IV.

From the data in Table IV, it can be noticed that in treatment A, B, C and D the concentration of phosphorus in roots, shoots and fruits expressed as Mg P/gm. D.W. increases with lengthening the period of initial phosphorus supply. On the other hand, there was no appreciable increase in phosphorus concentration in plant tissues when phosphorus was also supplied in the medium during the fifth period (treatment E).

TABLE IV

The effect of the presence and absence of phosphorus in the medium on the phosphorus content of the plant tissues (Mg P/gm. D. W.)

Treatment designation	weeks with or without P	Average P concentration in		
		roots	shoots	fruits
A	+ 3	1·295	0·982	2·589
B	+ 6	1·875	1·250	3·661
C	+ 9	2·777	1·920	4·911
D	+12	2·857	2·321	6·696
E	+15	2·865	2·325	6·698
F	— 3	2·411	3·304	6·698
G	— 6	3·661	4·821	7·321
H	— 9	2·054	3·214	7·857
I	—12	1·339	0·982	4·554
J	—15	0·893	0·580	2·411
S. E. of treatment means		0·0047	0·028	0·160

The general trend of these results is that during the first six weeks of phosphorus supply (treatment C), sufficient phosphorus is absorbed to meet the needs of the plant up to maturity. The further supplies of phosphorus absorbed during later periods had no significant influences on yield, merely increasing phosphorus concentration in the tissues.

(b) Phosphorus absent at beginning :

When phosphorus was available after 3, 6 and 9 weeks of initial omission (treatments F, G and H), its level in the tissues, as estimated at the close of the experiment, was higher than that of the continuous phosphorus cultures, suggesting a considerable intake when phosphorus was eventually supplied, without, however, sufficient response on the part of the plant to enable it to utilize this phosphorus in the production of additional dry matter. When initial phosphorus starvation was increased to 12 weeks (treatment I) and 15 weeks (Treatment J), the concentration of phosphorus in roots, shoots and fruits was comparatively decreased.

It is of vital importance to notice that inspite of the ability of the plants to absorb relatively high quantities of phosphorus after initial phosphorus starvation, they were unable to utilize these quantities satisfactorily. This also emphasizes the drastic influence of phosphorus starvation during the early stages of growth on the later development of the plant.

A true picture may be given by calculating the total amount of phosphorus of the different parts of the plants of the various treatments. This is clearly shown in Table V and graphically illustrated in Fig. 2.

TABLE V

Total phosphorus content of the different parts of the plants of the various treatments (mgm.)

Treatment designation	Weeks with or without phosphorus	Total phosphorus in roots per plant (mgm.)	Total phosphorus in shoots per plant (mgm.)	Total in phosphorus fruits per plant (mgm.)	Total phosphorus per plant (mgm.)
A	+ 3	5·348	10·692	13·308	29·348
B	+ 6	8·719	18·575	37·745	65·039
C	+ 9	11·544	30·643	47·833	90·020
D	+12	12·399	35·163	71·178	118·740
E	+15	13·952	38·246	71·468	123·666
F	— 3	8·993	42·952	48·226	100·171
G	— 6	6·187	36·206	30·236	72·629
H	— 9	2·013	7·810	15·557	25·380
I	—12	1·714	1·507	3·188	6·509
J	—15	0·982	0·963	1·664	3·609

It can be clearly seen that in treatments A, B, C and D the total amount of phosphorus of the various parts of the plants progressively increased by lengthening the period of phosphorus presence in the culture solution. There was, however, an increase, though slight, in cultures of treatment G as a result of lengthening the period of phosphorus supply till the close of the experiment. The same observations can be also detected from the results of plants initially deprived of phosphorus; the longer the period of phosphorus deprivation, the lower the phosphorus content of the various parts of the plants.

These results indicate the importance of the presence of phosphorus in the medium from the end of the third week till the end of the ninth week after sowing. This

is illustrated by the fact that though cultures initially deprived of phosphorus during such critical period (treatment G) contain higher amount of phosphorus than those initially supplied with phosphorus during such critical period only [treatment B], yet the latter treatment gave far greater yield, indicating a satisfactory utilization of phosphorus when supplied at the proper period. This confirms the previous conclusion that the necessity of phosphorus for proper development of the broad bean plant lies between the third and ninth weeks after sowing.

Such conclusion is similar to the findings of Brenchly [1929] and Gericke [1925] who stated that wheat and barley take up much of their phosphate in the early stages of their growth and starvation at this period cannot be recouped by a good supply later.

The present results are also in agreement with those obtained by Golle and Damidenko [1940]. They have shown that phosphorus is needed during the early periods of development. Absence of phosphorus during such critical periods of development is reflected in the decrease of the absolute weight of the seeds and their fat content.

Conclusion

It is evident from the results of the present experiment that the presence or absence of phosphorus during the early stages of growth is of vital importance. The actual phosphorus requirements of the broad bean plant in the earliest days of growth is exceedingly small and the minimum amount supplied from the cotyledons at that stage ensures proper growth up to the end of the fourth week after sowing. In this connection, a determination of the amount of phosphorus contained in the broad bean seeds was made. The average values per seed thus obtained were as follows :

Phosphorus concentration in dry seed . .	3·929 mg P/gm D.W.
Total phosphorus per seed	3·413 mg P

So it may be suggested that the presence or absence of phosphorus in the medium during the first three weeks after sowing has no significant influence on the growth, provided adequate supplies of phosphorus become available later. The critical period for the necessity of phosphorus seems to lie between the third to the ninth weeks after sowing. When sufficient amount of phosphorus is present in the medium during such period, growth proceeds normally as well and nearly to the same degree as though phosphorus was present throughout. With increased phosphorus supply during initial period the further supplies of phosphorus have no significant influence on dry matter production, merely increasing the phosphorus concentration present in the tissues. At the same time the absence of phosphorus during the critical period has a definite influence on the later development of the plant. With longer periods of phosphorus deprivation, growth is steadily depressed.

SUMMARY

This paper deals with the effect of the presence and absence of phosphorus at various stages of growth of *Vicia faba*.

The plants were grown in sand-cultures and were supplied with plus or minus-phosphorus nutrient solutions for varying lengths of time.

The presence of phosphorus in the medium during the fourth and sixth week after sowing, does not enable the plant to maintain a normal growth in later stages of growth when starvation occurs.

Provided phosphorus is available from the beginning of the fourth to the end of the ninth weeks after sowing, plants continue to grow as rapidly as cultures continuously supplied with this element. During that period the plant can absorb enough phosphorus for the maintenance of normal growth throughout. Further supplies of phosphorus during later periods of growth have no significant influence on dry matter production, merely increasing phosphorus concentration in the tissues.

Absence of phosphorus in the medium during the critical period of growth has a drastic effect on the growth and development of the plant. When phosphorus is eventually supplied later, considerable amounts of this element are absorbed, without, however, sufficient response on the part of the plant to enable it to utilise this phosphorus in the production of additional dry matter.

As the period of phosphorus deprivation increases, the dry matter production decreases. With complete absence of phosphorus throughout the whole period of the experiment, the growth eventually comes to a standstill. Plants suffering from phosphorus deficiency showed low shoot/root ratios.

The symptoms of phosphorus deficiency on leaves were : a yellow colour and early death ; a marked reduction in the rate of leaf-production and individual leaf-area.

The critical period for the necessity of phosphorus for proper fruit and seed production seems to lie in the first six weeks after the complete germination of the seed. The absence of phosphorus during that critical period has a marked influence on the later production of fruits and seeds.

REFERENCES

Brechley, W. E., (1929). The phosphate requirements of barley at different periods of growth. *Ann. B. t.* **43**, 89

Gericke, W. F. (1924). The beneficial effect to wheat growth due to depletion of available phosphorus in cultural media. *Science, n. s.* **60**, 297. 1924

—— (1924). The beneficial effect to plant growth of the temporary depletion of some of the essential elements in soil. *Science, n.s.* **60**, 321.

—— F. (1925). Salt requirements of wheat at different growth phases. *Bot. Gaz.* **80**, 410.

Golle, V. P. and Demidenko, T. T. [1940]. Critical periods in the nutrition of the castor oil plant. (*Chem. Abst.* **1344**)

Hewitt, F. J. (1945). Experiments in mineral nutrition. The visual symptoms of mineral deficiencies in crop plants grown in sand cultures. *Ann. Rep. Long Ashton Res. Stat.* 1944. P. 50. 1945

King, E. J. [1951]. *Micro-Analysis in Medical Biochemistry.* Churchill, London

Maximov, N. A. [1938]. *Plant Physiology.* Mc Graw-Hill Book Company

Miller, E. C. (1938). *Plant physiology.* Mc Graw-Hill Book Company.

A PROMISING '*BAJRA*' VARIETY FOR DELHI STATE

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(With 1 Text-Figure)

BAJRA (*Pennisetum typhoides* Stapf. and Hubb.) is one of the important food crops of India. According to a recent estimate, it occupied about 26 million acres of land during the '*kharif*' season of 1953-54. This crop thrives well on sandy soils and is largely grown in central, southern and western India. The moisture requirements of *bajra* are not heavy and, with a well distributed rainfall, it has been known to grow on as little as 9 inches of rain.

Delhi, with inadequate and irregular rainfall, falls within a semi-arid region. The conditions are almost akin to the adjoining arid regions of Rajasthan and South and South-west Punjab. Minor portion of the cultivable land in Delhi State, of which *bajra* occupies 48,000 acres, is rainfed. Except in case of total failure of monsoons, '*bajra*' unlike maize survives even on a small quantity of rain. It would, therefore, always remain the standby of farmers of Delhi State.

With the above background in view, it seems desirable to improve the yield of *bajra* in Delhi State by introducing new and high-yielding varieties. A collection of some of the improved strains from different parts of the country was made for trial in the Division of Agronomy, Indian Agricultural Research Institute, New Delhi, three years ago and the results obtained are given below :

Experimental

1. Varieties : V1 = *Bajra* local (standard)
   V2 = *Bajra* B-207 (Nadiad) Baroda
   V3 = *Bajra* Cumbu No. 1 (Madras)
   V4 = *Bajra* Cumbu No. 2 (Madras)
   V5 = *Bajra* Cumbu No. 3 (Madras)
   V6 = *Bajra* Pb. T-55 (Punjab)
   V7 = *Bajra* Pb. A 1/3 (Punjab)
2. Lay-out : 4 randomized blocks
3. Plot-size : 27′ × 22′ = 1/73·33 acre
4. Rotation : Fallow-*bajra*
5. Soil : Medium loam

Results

Table I

	Yield of grain in md. per acre			
	1952	1953	1954	Average (3 years)
V1 *Bajra* local	7·99	7·34	8·43	7·92
V2 *Bajra* B-207	11·09	12·83	9·08	11·00
V3 *Bajra* Cumbu No. 1	5·51	12·37	7·43	8·43
V4 *Bajra* Cumbu No. 2	0·37	8·93	7·97	5·75
V5 *Bajra* Cumbu No. 3	5·97	8·25	7·97	7·40
V6 *Bajra* Pb. T-55	9·78	15·11	9·56	11·48
V7 *Bajra* Pb. A1/3	6·99	11·91	7·56	8·82
Average	6·81	10·96	8·28	..
'F' Value	Sig. 1 per cent	Sig. 1 per cent	Not Sig.	Sig. 1 per cent
SEm ±	1·45	0·53	0·93	0·59
C.D. 1 per cent	5·85	2·16	..	2·40
5 per cent	4·27	1·57	..	1·75

BAJRA T-55. Promising *bajra* variety.

Average effect of varieties × years was found significant at 5 per cent

SEm ± 1·35

C.D. at 5 per cent 3·82

Effect of years was also significant at 1 per cent

SEm ± 0·48 C.D. 1 per cent = 1·86
C.D. 5 per cent = 1·37

Conclusions at 5 per cent

1952 :	V2,	V6,	V1,	V7,	V5,	V3,	V4
1953 :	V6,	V2,	V3,	V7,	V4,	V5,	V1
1954 :	V6,	V2,	V1,	V5,	V4,	V7,	V3
Average (3 years) :	V6,	V2,	V7,	V3,	V1,	V5,	V4

In 1952, varieties V2 and V6 were found significantly superior to V5, V3 and V4, but V2, V6, V1 and V7 did not differ significantly among themselves and so was the case with V1, V7, V5, and V3, as well. Variety V4 yielded lowest.

In 1953, the variety V6 was significantly superior over all other varieties. V2, V3 and V7 did not show significant difference among themselves. They were, however, significant over the rest.

In 1954, differences between varieties were not found to be significant though Pb. T-55 (V6) gave the highest yield.

The average effect of 3 years has shown that varieties V6 and V2 have given significantly higher yields over others though the difference between them is not significant. The varieties V1, V3, V5 and V7 have not shown significant differences within themselves. The yield obtained from V4 was the lowest.

On the basis of the above data, it was decided to introduce Pb. T-55 in the 19 villages of Delhi State, where results of research are brought into common practice on the fields of cultivators, under the supervision of the staff of Indian Agricultural Research Institute. A short description of this variety is as follows :

Pb. T-55.—A medium maturing variety of 3 months' duration ; drought resistant ; height, about 75 cm ; ears, medium in thickness, long, with compact setting ; a high yielder which has given an average yield of 11½ md. per acre in Delhi villages ; evolved by the Economic Botanist, Punjab.

The seed of this variety was first multiplied in isolated plots on the farm attached to the Institute. The pure seed thus produced was distributed in the villages. Regular supervision of the crop grown by farmers for seed is kept and roguing arranged. The maximum yield so far obtained from this variety in villages has been 22 md. per acre.

INFLUENCE OF CLIMATIC FACTORS ON SALINITY OF INDIAN SOILS

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(With 4 Text-figures.)

THE rate of formation of soluble salts in a soil is decidedly influenced by the nature of the parent material ; the total salt content, nevertheless, has been observed by McCool and Millar [1920] to be dependent mainly upon rainfall. Scherf [1933] who made a detailed study of the influence of the external factors on the properties of soil found, that in actual accumulation of soluble salts, climatic factors were more important than others, the parent materials having comparatively little influence over the same [Ramnan, 1911 ; Glinka, 1927 ; Wolfanger, 1927]. This had also been previously borne out by the results of experiments of Lipman and Waynick [1916], who determined the salt contents of soil blocks brought from one locality and kept them in different localities under different climatic conditions. They observed that soil blocks from California kept at Maryland and Kansas showed increases in salt contents over that kept at California itself. Decrease in salt contents of soils under increased rainfall had been found to be due to greater leaching [Upson and Calvin, 1916 and by runoff Duley, 1925 ; Kanitkar *et al.*, 1941].

On the basis of his concept of chemical weathering of soils as hydrolytic decomposition of silicates, Ramnan [1911] introduced temperature as an active agent in the formation and classification of soils. Subsequent work indicated close relationships between temperature and many important soil properties [Jenny 1941]. Gustafson [1922] and Wheeting [1925] found that rise in temperature increased the solubilisation of soil material and evaporation of moisture with rise in temperature indirectly acted against the leaching out of soluble salts from the soil mass by percolation.

In a study of the effect of simple climatic factors like rainfall or temperature on any soil property, the effect of one has necessarily to be eliminated to study the effect of the other. This difficulty has been removed to a certain extent by the use of single value climatic constants. Two most commonly used single value climatic constants are Lang's rainfactor [Lang, 1920] which takes into account the precipitation temperature ratio and the Meyer's N.S. Quotient [Meyer, 1926] which involves the use of the ratio between precipitation and absolute saturation deficit of the air.

During the present investigation, the effect of annual rainfall and temperature on salinity of 43 virgin soil profiles collected from different parts of India was determined simultaneously as grouping of the soils into isohyetal and isothermal classes proved rather unsatisfactory. Soluble salt contents of the soils were also correlated with Lang's rainfactor and Meyer's N. S. Quotient of the soil localities. In evaluation of salinities of soils, profile average salinities in addition to surface salinities were taken into consideration since it appeared that surface salts could hardly be used as true indices of soil salinity, because of the fact that distribution of salts along the profile was found to depend mainly upon the season [Millar, 1922, 1923 ; Larson, 1928].

Material and methods

Soils. Fortythree virgin soil profiles up to five feet depth were collected from different parts of India. Each profile usually consisted of five samples each representing one foot depth.

Method of collection of soil samples. The soil samples were collected from pits dug in undisturbed areas in each locality and the soil removed from the walls at intervals of one foot depth.

Climatic factors. The data concerning average annual rainfall, average annual temperature, Lang's rainfactor and Meyer's N. S. Quotient of the different soil localities studied had been compiled from Annual Summary of the India Weather Review [Pt. A 1938].

Salt content. One hundred grams of soil were treated with 500 c.c. of CO_2-free distilled water and shaken occasionally. The soil suspension was filtered after keeping overnight in a Pasteur Chamberland filter [Stewart 1926]. Suitable aliquots from the filtrate were evaporated to dryness and the weight of the dry residue corresponding to 100 gm. of soil was taken to represent the salinity of the soils.

Surface and profile average salinity. Soluble salt content of the surface one foot soil expressed in mg. per 100 gm. of soil was taken as the surface salinity. The average of the salt contents of the soil samples at different depths in the same profile expressed in the same units was taken as the profile average salinity.

Results

The climatic data of the different soil localities have been given in Table I. In Table II are given the salt contents of the surface soils and those averaged over five feet depth of each profile.

TABLE I

Climatic factors of the soil localities

Soil locality	Annual rainfall (R) (m.m.)	Annual temperature (T) (°C)	Rainfactor (F) (m.m./°C)	N. S. Quotient (Q) (m.m./m.m. Hg)
Akola	793·0	26·8	29·7	141·3
Anakapalle	942·0	27·3	34·5	182·2
Berhampur	1142·0	26·5	43·1	301·5
Chandkhuni	1340·0	26·1	51·3	246·3
Chinsurah	1450·0	26·2	58·8	430·1
Coimbatore	566·0	26·6	21·3	162·0
Dacca	2149·0	25·8	83·3	579·2
Delhi	682·0	25·0	27·3	123·6
Gurdaspur	755·7	23·6	31·9	188·0
Hagari	521·0	27·8	18·7	91·2
Haripur	506·5	22·9	22·5	102·1
Indore	841·0	24·5	34·3	167·3
Jorhat	2416·0	23·1	104·6	1725·2
Kangra	1870·1	19·2	97·4	656·0
Karachi	192·0	25·6	7·5	35·7
Karimgunj	3160·0	24·9	126·9	1322·3
Kharua	791·0	24·8	31·9	149·9
Kheri	1400·0	24·5	57·1	304·6
Koilpatti	852·0	28·9	29·5	154·4
Labhandi	1292·0	26·1	49·5	237·5
Lahore	498·0	23·9	20·9	105·8
Lyallpur	334·0	24·1	13·9	60·6
Makrera	499·0	24·9	20·0	104·8
Mianwali	331·0	23·1	14·3	67·1
Mirpurkhas	178·0	27·1	4·5	32·0
Nandyal	661·0	28·1	23·5	127·0

TABLE I—*contd.*

Climatic factors of the soil localities

Soil locality	Annual rainfall (R) (m.m.)	Annual temperature (T) (°C)	Rainfactor (F) (m.m./°C)	N. S. Quotient (Q) (m.m./m.m. Hg)
Nagpur	1244·0	26·9	46·2	225·0
Padegaon	658·0	26·2	25·1	137·0
Padrauna	1335·0	25·1	53·2	328·0
Peshawar	343·2	22·9	15·3	69·2
Powerkhera	1240·0	25·5	48·6	236·8
Pusa	1179·0	24·9	47·1	207·9
Ranchi	1455·7	23·8	61·3	318·5
Rangpur	2084·0	24·7	84·4	694·8
Sahjahanpur	916·0	25·1	36·5	203·1
Sakrand	171·0	27·1	6·3	30·8
Samalkot	993·0	27·9	35·6	223·0
Sirsi	3051·0	25·3	120·6	886·9
Surat	1041·9	27·1	38·4	202·4
Sylhet	2836·0	24·9	113·9	1191·5
Tabiji	525·0	24·9	21·1	110·2
Taliparamba	3118·0	27·3	114·2	762·4
Waraseoni	1352·0	24·5	55·2	275·2

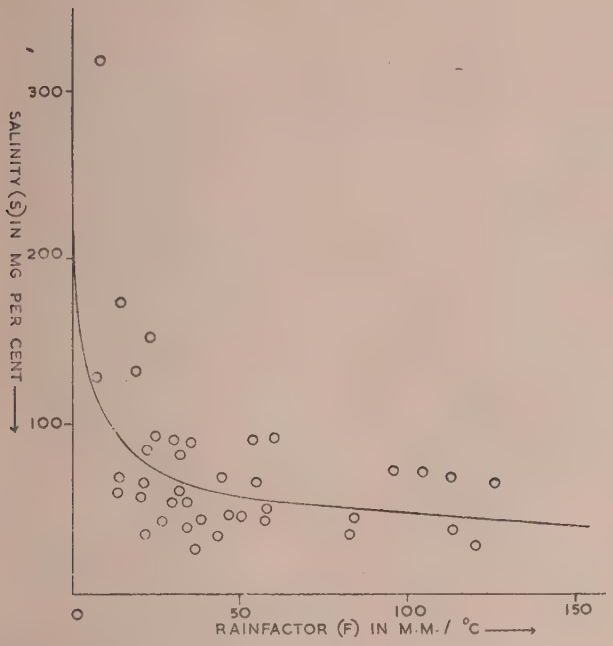

Fig. 1.—Langs rainfactor and surface salinity of soils

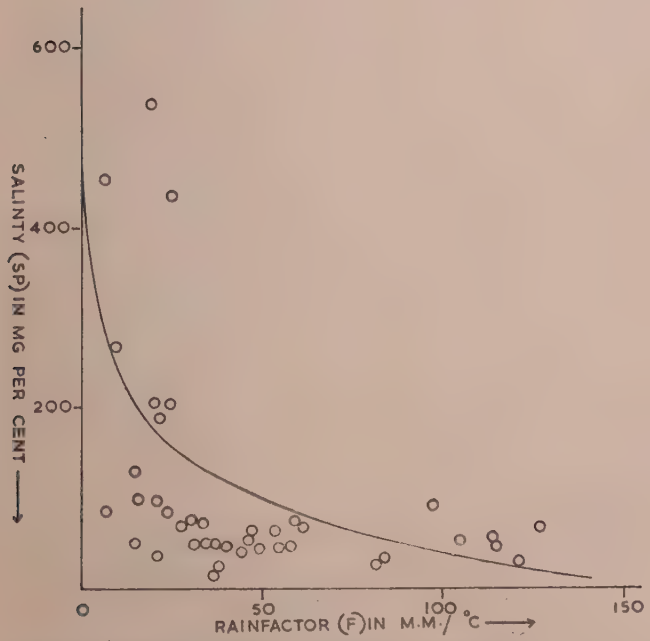

Fig. 2.—Lang's rainfactor and profile average salinity of soils

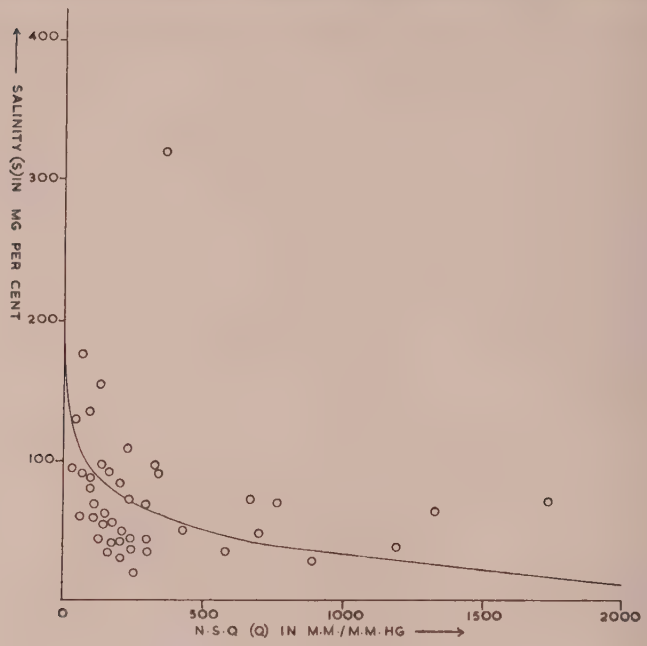

Fig. 3.—Meyer's N. S. Q. and surface salinity of soils

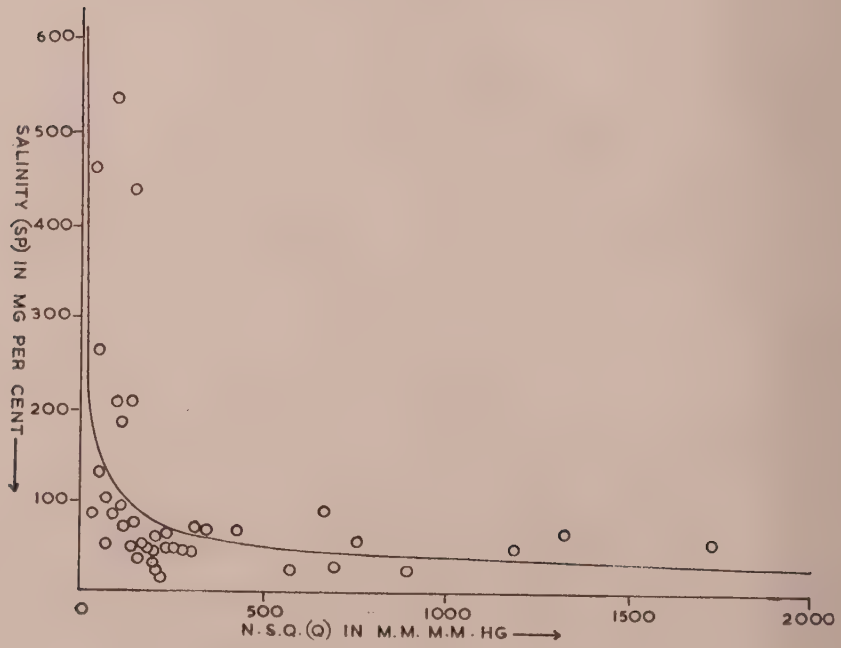

Fig. 4.—Meyer's N. S. Q. and profile average salinity of soils

TABLE II

Total soluble salts of the soils at the surface and as average over the profile

(Expressed as mg. per cent)

Soil locality	Surface salinity (S)	Profile average salinity (Sp)
Akola	53	72
Anakapalle	40	45
Berhampur	35	41
Chandkhuni	20	45
Chinsurah	51	73
Coimbatore	35	35
Dacca	35	23
Delhi	43	71
Gurdaspur	84	73
Hagari	135	535
Haripur	88	85
Indore	55	49
Jorhat	71	50
Kangra	72	91
Karachi	320	262
Karimgunj	65	65

TABLE II—*contd.*

Total soluble salts of the soils at the surface and as average over the profile

(Expressed as mg. per cent)

Soil locality	Surface salinity (S)	Profile average salinity (Sp)
Kharua	63	49
Kheri	43	42
Koilpatti	93	1122
Labhandi	36	43
Lahore	58	186
Lyallpur	60	133
Makrera	80	205
Mianwali	90	50
Mirpurkhas	95	84
Nandyal	155	203
Nagpur	70	53
Padegaon	95	438
Padrauna	91	63
Peshawar	175	100
Powerkhera	44	42
Pusa	48	59
Ranchi	93	66

TABLE II—*contd.*

Total soluble salts of the soils at the surface and as average over the profile

(Expressed as mg. per cent)

Soil locality	Surface salinity (S)	Profile average salinity (Sp)
Rangpur	46	30
Sahjahanpur	25	24
Sakrand	129	454
Samalkot	110	15
Sirsi	28	24
Surat	43	44
Sylhet	39	46
Tabiji	68	93
Taliparamba	70	52
Waraseoni	68	44

DISCUSSION OF RESULTS

There is no first hand information as to whether the salt content of the surface soil (S) or that averaged over the profile (Sp) characterises the salinity status of a soil. It is obvious, however, that while S is liable to be influenced by transient factors, Sp expresses, more or less, the permanent salinity status of a soil as a result of climatic influences.

As division of the soil localities into isohyetal or isothermal groups is not very satisfactory because of large variations in annual rainfall or annual temperature, study of the simultaneous effect of rainfall and temperature on soil salinity taking the factors as independent variables is considered desirable. Such studies indicate that the relationship between surface salts on one hand and the rainfall and temperature on the other is best expressed by the equation $\log_{10} S = 2{\cdot}9335 - 0{\cdot}4101 \log_{10}$

R+0·0031 T, where S is the salt content of the surface soil in mg. per 100 gm. of soil, R, the average annual rainfall of the locality in m.m. and T, the average annual temperature in degrees °C.†

The expression shows that the annual rainfall is the predominant factor in determining the salinity of the surface soils. The effect of annual temperature is evident in the case of the profile average salinity, though the effect of rainfall is much more expressed than the effect of temperature. The relationship between profile average salt content on one hand and rainfall and temperature on the other has been found to be best expressed in the form $\log_{10}$ Sp=1·5890—0·6412 $\log_{10}$ R+0·0853 T, where Sp is the profile average salts in mg. per 100 gm. of soil, R, the average annual rainfall in m.m. and T, the average annual temperature in degrees °C.††

Coefficient	Value	±S E (b)	t=b/S E	Correlation coefficient		
				Total	Partial	Multiple
a	2·9335					
b_1	—0·4101	0·0986	4·16**	—0·5543	—0·5542**	0·5547**
b_2	0·0031	0·0212	0·15	0·0236	0·0272	

Coefficient	Value	±S E (b)	t=b/S E	Correlation coefficient		
				Total	Partial	Multiple
a	1·5890					
b_1	—0·6412	0·1505	4·26**	—0·7799	—0·5637**	0·6284**
b_2	0·0853	0·0323	2·64*	0·2670	0·3895*	

Rainfall and temperature are somewhat combined in single value climatic constants like Lang's rainfactor and Meyer's N. S. Quotient. The relationship between the rainfactor and surface salinity of soils is negative and highly significant

* $\log_{10} S = a + b_1 \log_{10} R + b_2 T$ ** $\log_{10} Sp = a + b_1 \log_{10} R + b_2 T$

(r=—0·5378) and that between rainfactor and profile average salinity negative and significant at 5 per cent only (r=—0·3379) (Figs. 1 and 2). The relationships can be expressed in the form of equations—$\log_{10}$ S=2·3832—0·3623 $\log_{10}$ F and Sp =437·8523—200·2042 $\log_{10}$ F where S and Sp are the surface and profile average salinities respectively in mg. per 100 gm. of soil and F is the rainfactor of the locality. The relationship between surface salinity and N.S.Q. (r=—0·4990) and profile average salinity and N.S.Q. (r=—0·5022) are also negative and highly significant (Figs. 3 and 4). The relationships can be expressed in the form of equations S=218·5642—62·1972 $\log_{10}$ Q and $\log_{10}$ Sp=2·9586—0·4648 $\log_{10}$ Q, where S and Sp are surface and profile average salinities in mg. per cent respectively and Q is the N. S. Quotient of the locality. This is quite expected as both the single value climatic constants increase with increase of rainfall and marked decrease of S and Sp. with higher F and Q demonstrates the predominant effect of rainfall on salinity of soils over that of temperature. In other words, the effect of temperature in increasing the salinity of soils is considerably outstripped by general leaching with higher rainfall and finally a resultant decrease in the salt content of the soils is observed.

Summary

During the present investigation, soluble salt content of surface soils and average of salt contents of different depths of an entire profile of five feet depth of 43 virgin soil profiles collected from different parts of India have been correlated with average annual rainfall, average annual temperature, Lang's rainfactor and Meyer's N. S. Quotients of the soil localities.

The combined effect of annual rainfall and temperature on the surface and profile average salinities of soils could be expressed by the equations—

$\log_{10}$ S=2·935—0·4101 $\log_{10}$ R+0·0031 T and $\log_{10}$ Sp=1·5890—0·6412 $\log_{10}$ R+0·0853 T respectively, where S and Sp are the surface and profile average salinities of soils in mg. per 100 gm. of soil, R, the average annual rainfall in m.m. and T, the average annual temperature in degrees °C.

The relationships of surface and profile average salinities with rainfactors of soil localities could be expressed in the equations—

$\log_{10}$ S=2·3832—0·3623 $\log_{10}$ F and Sp=437·8523—200·2042 $\log_{10}$ F respectively, where S and Sp are surface and profile average salinities in mg. per cent respectively and F is the rainfactor.

The relationship of surface and profile average salinities with N. S. Quotients of the soil localities could be expressed in the form of equations.—

S=218·5642—62·1972 $\log_{10}$ Q and

$\log_{10}$ Sp=2·9586—0·4648 $\log_{10}$ Q respectively, where S and Sp are surface and profile average salinities in mg. per cent and Q, the N. S. Q. of the soil locality.

Rainfall seemed to have a more predominant effect in determining the salinity of a soil than temperature.

ACKNOWLEDGEMENT

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REFERENCES

Annual Summary of India Weather Review (1938) Pt. A.

Duley, F. L. (1925). The loss of soluble salts in run off water. *Soil Sci.*, **21**, 401—409

Glinka, D. K. (1927). *The great Soil Groups of the World and their development*, Translation by C. F. Marbut, pp. 5—8

Gustafson, A. F. (1922). The effect of drying soils on their water soluble constituents, *Soil Sci.*, **13**, 173—214

Kanitkar, N. V., Daji, J. A. and Gokhale V. K. (1941). Surface, run off and soil erosion from arable lands in the Bombay Deccan. *Indian J. Agric. Sci.*, **11**, 493—545

Jenny, H. (1941). *Factors of Soil Formation*, McGraw Hill Book Co. Inc. New York and London

Lang, R. (1920). H. Jenny's, *Factors of Soil Formation* Original not seen

Larson, H. W. E. (1928). The relation of the concentration of the calcium ions required by alfalfa to the amount present in the soil solution, *Soil Sci.*, **25**, 399—408

Lipman, C. B. and Waynick, D. D. (1916). A detailed study of the effect of climate on important properties of soils. *Soil Sci.*, **1**, 5—49

McCool, M. M. and Millar, C. E. (1920). The formation of soluble substances in soils taken from widely separated regions. *Soil Sci.*, **10**, 219—235

Meyer, A. (1926). H. Jenny's *Factors of Soil Formation* Original not seen

Millar, C. E. (1922). Further studies on the soluble salt contents of field soils. *Soil Sci.*, **13**, 433—448

Millar, C. E. (1923). Studies on virgin and depleted soils. *Soil Sci.*, **16**, 433—448

Ramman, E. (1911). *Bodenkunde*, Verlag Julius Springer, Berlin

Scherf, E. (1930). J. S. Joffe's *Pedology* Original not seen

Stewart, G. R. (1918). Effect of season and crop growth in modifying soil extract, *J. Agric. Res.*, **12**, 311—364

Upson, F. W. and Calvin, J. W. (1916). The loose soils of the Nebraska portion of the transition region V. The water soluble constituents. *Soil Sci.*, **1**, 377—386

Wheeting, L. C. (1925). The influence of liming, temperature and compaction on the movement of soluble salts in the soils. *Soil Sci.*, **19**, 459—466

Wolfanger, L. A. (1930). *The Major Soil Divisions in the United States*, page 7, John Wiley and Sons. New York

GROWTH OF AZOTOBACTER IN RICE SOIL

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RICE soils remain alternately dry and waterlogged. From transplantation to harvest, the soils remain under water and for the remaining part of the year dry. According to Pearsall [1950], the surface layer of a submerged soil is in an oxidising condition and the layer below is in a reducing state. Scott and Evans [1955] observed complete disappearance of dissolved oxygen from uncropped soils within 10 hours, after they have been flooded. The results of a pot experiment conducted by De and Mandal [1957] showed that cropped rice soils generally contain only a very small amount of dissolved oxygen. All these observations will lead one to conclude that the conditions occurring in waterlogged rice soils are not favourable for the growth of strictly aerobic micro-organisms like Azotobacter. It can be concluded, therefore, that the Azotobacter population of these soils might have been adversely affected as a result of periodic and regular exposure to unfavourable conditions year after year over a long period. The object of the present investigation is to obtain some informations on the growth and activity of Azotobacter in rice soils. It is hoped that such informations will be helpful in understanding the role of this group of organism in maintaining the fertility of rice soils.

Material and Methods

Occurrence of Azotobacter in soils of different pH

More than 200 soil samples (0–6 in.) were collected from different parts of West Bengal. As the samples had to be brought from distant places, it was not always possible to examine them fresh. Consequently, the samples on arrival were air-dried, sieved through 2 mm. sieve and then kept at 50 per cent water holding capacity for a week at room temperature. The occurrence and the numbers of Azotobacter were determined on these soils. To detect the occurrence of Azotobacter, small soil grains were scattered over the surface of nitrogen-free agar plates* made with glucose, mannite, canesugar and dextrin. The plates were incubated at 35°C and periodically examined for over a period of 3 weeks. Where Azotobacter was present, the growth consisted almost entirely of typical colonies of *Azotobacter chroococcum* which could be easily distinguished from small colonies of bacteria and fungi which also appeared on the plates. *Azotobacter indicum* was very scarce even in soils of low *p*H ; other known species of Azotobacter were absent. In this article, the word 'Azotobacter' thus refers to *Azotobacter chroococcum* only.

*Carbohydrate—10 gm., K_2HPO_4—0·5 gm., $MgSO_4$. $7H_2O$—0·2 gm., $CaCl_2$—0·1 gm., $CaCO_3$—5·0 gm., Na_2MoO_4. $2H_2O$—0·001 gm., Na_2WO_4. $2H_2O$—trace, $FeCl_3$. $6H_2O$—trace, Agar—20 gm. and water 1000 cc.

TABLE I

Occurrence of Azotobacter in soils of different p*H*

*p*H range	Number of soils examined	Number of soils showing Azotobacter growth	Per cent of total number of soils showing Azotobacter growth
5·0—5·5	11	0	0
5·6—6·0	18	3	16·7
6·1—6·5	71	10	14·1
6·6—7·0	58	24	41·3
7·1—7·5	24	16	66·7
7·6—8·0	19	16	84·2
8·1—8·5	13	11	84·6
8·6—9·0	3	3	100
TOTAL	207	83	40

Table I shows that Azotobacter was present only in 40 per cent of the soils examined. Most of the soils had *p*H values above 6, which is the lower limiting *p*H for the growth of *Azotobacter chrooccocum* [Gainey 1923]. The absence of Azotobacter in the above soils, therefore, is not due to unfavourable *p*H.

Azotobacter numbers

The numbers of Azotobacter in soil was determined by the method developed by Jensen [1940]. In this method 0·2 cc. portions of a soil dilution of 1 : 10 are placed on three sterilized petri dishes containing hardened dextrin-agar medium* and evenly spread over by means of a L-shaped glass rod. Excess water is allowed to evaporate. The plates are incubated at 35°C for five days after which the colonies are counted. An advantage of this method is that the colonies formed are discrete and very easily distinguishable.

The results in Table II show that Azotobacter are present in rice soils in small numbers and that there is no relation between Azotobacter numbers and *p*H of the soil.

*K_2HPO_4—0·5 gm., $MgSO_4$, $7H_2O$—0·2 gm., Na_2Mo_4O, $2H_2O$—0·025 gm., $CaCO_3$—5 gm., $FeCl_3$, $6H_2O$—0·05 gm., Dextrin—10 gm., Agar—20 gm. and water—1000 cc.

TABLE II

Azotobacter numbers per gram of oven dry soil

Soils	*p*H	Azotobacter numbers
Serampore	6·0	650
Burdwan	6·6	150
Swarupnagar	6·8	100
Tamluk	6·9	2000
Konnagar	7·0	50
Kharampur	7·3	300
Baruipur	7·3	2500
Jadupur	7·4	700
Belur	7·7	Innumerable
Chakmir	7·9	1800
Baduria	—	50
Beldanga	—	150

Nitrogen fixing capacity of Azotobacter

Nitrogen fixing capacity of Azotobacter isolated from different soils was determined by inoculating a standard inoculum containing 80-100 million cells into 100 cc. portions of nitrogen-free mannite solution and determining the nitrogen fixed after incubation for 7 and 15 days at 35°C. For isolation of the organism, several small soil grains were placed over the surface of a mannite agar plate and as soon as typical Azotobacter growth appeared round the soil particles, a little was taken out and streaked several times over the surface of a few plates of the same medium. After 72 hours, the plates were examined and the one showing a few discrete and well isolated colonies of Azotobacter was selected. Growth from these colonies was examined under the microscope until one pure culture was obtained. In cases where such a colony was not obtained, the process was repeated, but generally the organism was obtained in pure culture in the first attempt. Since the conditions of the soils may have an effect on nitrogen fixing capacity of Azotobacter and since this effect may disappear after the organism has grown outside the soil for several generations, in the above process of isolation the organism was not allowed to grow on artificial medium for more than one generation (on streaked agar plates) so that the effect of soil, if any, remains undisturbed as far as possible.

For preparation of the inoculum, a small amount of pure culture was suspended in a little sterile water and the density of cells in this suspension was determined by means of a hemocytometer. The preparation was then suitably diluted until one cubic centimeter contained 80—100 million cells. One cc. of this diluted suspension was used as inoculum.

TABLE III

Nitrogen fixation by Azotobacter isolated from different soils (nitrogen in mgm. per 100 cc. of the medium)

Soils	Millions of cells in the inoculum	N fixed in	
		7 days	14 days
Tamluk	80	3·2	9·8
Baruipur	80	4·3	10·8
Swarupnagar	80	1·1	8·1
Konnagar	84	6·6	10·4
Chakmir	84	2·9	8·1
Belur	95	2·8	6·7
Kharampur	95	4·2	9·4
Jadupur	96	2·9	7·0
Beldanga	96	4·9	9·5
Baduria	96	5·2	9·1
Burdwan	96	3·5	12·1
Average of 11 soils	..	..	9·2 mg.

From the results reported by different workers, the average fixation of nitrogen by *Azotobacter chrooccocum* is taken as 10 mg. per gram of sugar decomposed. In the present experiment *Azotobacter chrooccocum* isolated from 11 rice soils fixed on an average 9·2 mg. of nitrogen in course of 14 days, showing thereby that the nitrogen fixing capacity of Azotobacter of rice soils is not very much different from that of other soils. It will, however, be seen that fixation of nitrogen by Azotobacter, isolated from different soils, is different. For example, Azotobacter from the first three soils fixed 8·1 to 10·8 mg. of nitrogen, inspite of the size of the inoculum being the same in all cases (80 million cells). Similarly, in the case of last 4 soils the inoculum was 96 million cells, but the fixation varied from 7 to 12·1 mg. These observations show that Azotobacter present in different soils have different nitrogen fixing capacity. In other words, the conditions of the soils have an influence on the nitrogen fiixing capacity of Azotobacter.

Inoculation of Azotobacter into soils

Several soils in which Azotobacter was absent were inoculated with a suspension of the organism in water and then kept at room temperature for 15 days during which the moisture contents of the soils were maintained at 50 per cent of the water holding capacity. At the end of this period, the soils were tested for the presence of Azotobacter by inoculating several grains on the surface of a nitrogen-free-mannite agar plate. The soils were again inoculated, kept for another 15 days and then tested as above.

TABLE IV

Occurrence of Azotobacter in soils after inoculation

Soil	*p*H	Growth of Azotobacter	
		15 days after inoculation	15 days after inoculation
Chandrakona	5·8	0	++
Layekbazar	6·2	0	0
Makalhat	6·4	+++	+++
Gobindapur	6·8	0	+
Morar Union	6·9	0	0
Bankura	7·0	0	0
Ghatal	7·1	0	++
Sandeshkhali	7·8	0	0
Sagar	8·2	++	++

0 No growth. +Scanty growth. ++Good growth. +++Luxuriant growth.

Azotobacter did not survive in about 50 per cent of the soils examined inspite of favourable *p*H, temperature and moisture conditions. Only in two soils (Makalhat and Sagar) the conditions appear to be favourable for the growth of Azotobacter. In the remaining soils the organism survived only after re-inoculation, showing that these soils too are not very suitable for Azotobacter growth.

Occurrence of Antibiotics or other toxic Materials in soils

In order to find out whether the disappearance of Azotobacter from the inoculated soils, as observed in the previous experiment, is due to the production in soil of antibiotics or some other substances toxic to Azotobacter, 100 gm. portions of each of three soils from which Azotobacter rapidly disappeared after inoculation were separately shaken with acetone and with a mixture of acetone and acetic acid for

an hour. After standing for overnight, the extracts were filtered and the filtrate evaporated almost to dryness in a water bath at 60°C. The residue was extracted with water and then tested against a 16-hour old culture of Azotobacter by agar cup method. No inhibitory effect of the extracts on the growth of Azotobacter was noticed.

Supply of available phosphate and trace elements in soils

Two important requirements of Azotobacter are a liberal supply of available phosphate and presence of trace elements particularly molybdenum. To test whether these minerals are present in soils in amounts sufficient for an active growth of Azotobacter, several soils were examined by Winogradsky's soil plaque method [1926]. A description of this method has been given in an earlier publication by De and Datta Biswas [1952], to which reference may be made for details. Essentially the method consists in mixing soil with an energy material (mannite), then moulding the mixture into plaque with or without treatments, and finally counting the number of Azotobacter colonies that have appeared on soil surface after incubation. The different treatments applied to soils in the present experiment are as follows :

(1) Control (Soil+mannite)
(2) As (1)+Molybdenum (1 p.p.m.)
(3) As (1)+P_2O_5 (applied as K_2HPO_4)
(4) As (3)+trace elements (Mo, Cu, Zn, Mn, W ..... 1 p.p.m.)

Table V

Growth of Azotobacter on soil plaques (Figures represent the numbers of Azotobacter colonies in one sq. cm.)

Soil	Control	Treatments						
		Mo	P_2O_5	P_2O_5+Mo	P_2O_5+Cu	P_2O_5+Zn	P_2O_5+Mn	P_2O_5+W
Suri	0	0	Innumerable colonies					
Sonator	0	0	27	28	24	26	24	24
Chinsura	0	0	50	60	59	70	51	47
Panchanantala	0	0	Innumerable colonies					
Kamalgachi	0	0	30	28	50	37	47	37
Belur	0	0	Innumerable colonies					
Tollygunge	0	0	Innumerable colonies					

The results in Table V show that there was no growth of Azotobacter on plaques made with control soils with or without the addition of molybdenum. Growth, however, appeared after addition of phosphate. In presence of trace elements the growth barring few exceptions was not very much different from that in presence of phosphate along. The results thus show that the soils examined are deficient in phosphate but not in trace elements for an active multiplication of Azotobacter.

Effect of waterlogging of soils on the growth of Azotobacter

As stated in the introduction, the surface layer of a submerged soil is in an oxidising condition while the layer below is in a reducing state. In the latter layer, oxygen is either deficient or absent a condition which is distinctly unfavourable for the growth of a strictly aerobic organism like Azotobacter. In order to obtain an idea of the conditions of the growth of *Azotobacter* in different layers of rice soils about 500 gm. portions of each of three soils were introduced into three 500 cc. measuring cylinders which were wrapped up with black paper outside up to the height of the soil column, thus allowing algae and other aquatic organisms to grow only on the surface soil. The soils were brought to waterlogged conditions, and then transplanted with rice seedlings one in each cylinder. The plants were allowed to grow for two months during which the soil was maintained in waterlogged condition by periodic addition of water. At the end of this period, the entire soil column was brought out from the cylinders by gently pulling up the leaves of the plants. Three different layers (0 in.—1 in., 8 in.—9 in. and 16 in.—17 in.) were cut from each soil column and the Azotobacter numbers in each were determined by the method described before. The results given in Table VI show that there was a sharp fall of Azotobacter numbers even in the surface layer, where the conditions facilitate oxidation i.e. some amount of oxygen is present. In the bottom layers the numbers were even less. These observations clearly show that the conditions occurring in waterlogged rice soils are not favourable for the growth of Azotobacter. It seems unlikely therefore that these organisms play an important role on the nitrogen recuperation of rice soil under waterlogged conditions.

TABLE VI

Effect of waterlogging on the number of Azotobacter (Number in 1 gram of even dry soil)

Soil	*Azotobacter* at start	*Azotobacter* in different soil layers after 2 months		
		0 in—1 in.	8 in.—9 in.	16 in. —17 in.
Tollygunge	5916	506	191	131
Suri	2829	723	650	519
Krisnagar*	16078	5581	1948	1302

*Inoculated with *Azotobacter*.

CONCLUSIONS

The evidences obtained in this investigation do not show that Azotobacter play any important role in the nitrogen recuperation of waterlogged rice soils. The findings are thus not in agreement with the observations made by Uppal, Patel and Daji [1939] and by some of the indonesian workers [De Geus, 1954].

Summary

More than 50 per cent of the rice soils of West Bengal, inspite of favourable *p*H, do not harbour Azotobacter. Even in those soils where Azotobacter is present, the numbers are generally small. The nitrogen fixing capacity of the organism, however, is nearly as much as that of Azotobacter isolated from other sources. There was rapid disappearance of added Azotobacter from some of the rice soils inspite of favourable *p*H, temperature and moisture conditions. There is no evidence of the production of antibiotic or toxic substances in rice soils inhibiting the growth of Azotobacter. The rice soils examined are all deficient in phosphate, but not in trace elements. Evidences were obtained that waterlogging of soils has a depressing effect on the growth of Azotobacter, more in subsoil than in surface.

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REFERENCES

De, P. K. and Datta Biswas, N. R. (1952). Fixation of nitrogen in rice soils in the dry period. *Indian J. Agric. Sci.* **22,** 375—388.

De, P. K. and Mandal, L. N. (1957). Physiological diseases of rice. *soil. sci.* **84,** 367—376.

F. G. De Geus (1954). *Means of increasing Rice Production.*

Gainey, P. L. and Batchelor, H. W. (1923). Influence of the hydrogen ion concentration on the growth and fixation of nitrogen by cultures of Azotobacter. *J. Agric. Res.* **24,** 759—767.

Jensen, H. L. (1940). Contribution to the nitrogen economy of Australian wheat soils, with particular reference to New South Wales. *Proc. Linn. Soc.* New South Wales. **65,** 1—122.

Pearsall, W. H. (1950). The investigation of wet soils and its agricultural implications. *Emp. J. Exptl. Agric.* **18,** 289—298.

Scott, A. D. and Evans, D. D. (1955). Dissolved oxygen in saturated soils. *Proc. Soil. Sci. Amer.* **19,** 7—12.

Uppal, B. N., Patel, M. K., and Daji, J. A. (1939). Nitrogen fixation in rice soils. *Indian J. agric. Sci.* **9,** 689—702.

Winogradsky, S. (1926). Soil Microbiology II. Nitrogen fixing bacteria. *Ann. Inst. Pasteur,* **40,** 455-520.

SOIL FORMATION FROM ROCKS IN THE ARID ZONE IN N. W. PAKISTAN

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SOIL is the surface layer of the unconsolidated rock material on the earth crust which provides a natural medium for plant growth. It is a mixture of partially or wholly weathered rock fragments, which has been formed under the continuous and endless influence of soil forming processes. These processes have been reactive throughout the geologic history of the earth.

Soil formation as influenced by various factors commonly known as 'factors of soil formation' has been studied by a number of workers all over the world. The contribution of Dokuchaev [1950] in U.S.S.R., Marbut [1935] and Hilgard [1914] in U.S.A. stands as the most outstanding work in the field of soil science.

Dokuchaev was the first to appreciate the complex influence of natural agencies on soil formation. He concluded that the soil is the result of the combined activity and reciprocal influence of the following soil formers :

(*a*) Parent material

(*b*) Climate

(*c*) Age of the land

(*d*) Topography

(*e*) Plant and animal organism

The parent material, which is the initial state of soil system, is mainly passive. It undergoes a process of soil development under the influence of soil formers and the properties of soil thus produced manifest a significant corelation with the influencing factors. It is impossible to say whether these forces operate with equal strength in the conversion of soil material into soil. It is determined after undertaking a detailed study of the influencing factors in relation to soil characteristics. It has been observed that the soils of arid regions are richer in soluble constituents than those of humid areas. Hilgard [1897] after analysing a number of soil samples from arid and humid regions came to the conclusion that hydrochloric acid dissolves more total material from the arid than from humid soils. The works of Hilgard [1897] and Hissink [1938] show the effect of time upon soil formation. They observed that calcium carbonate is very susceptible to transformation with time. A soil containing 9-10 per cent of $CaCO_3$ in surface layer was completely freed from it within 300 years. Blockliger [1931] found that greater the number of bacteria on barren limestone rocks, the more advanced is the degree of rock decomposition.

There exists voluminous literature on soil characteristics as a function of different factors of soil formation in countries advanced in the field of soil science. No data exists in respect of the soils of this province. Soil formation from parent material has not been studied from pedologic point of view as yet. The present studies were undertaken to compile some information on the soil characteristics as developed under the associated soil forming factors commonly met within the province.

Experimental

Sites were selected in Mianwali and Jhelum districts, where evidence of soil formation from rocks under arid condition was quite conspicuous. Samples of the parent rock as well as the weathered material whose description is given in Table I were taken and their reaction studied in the laboratory.

The particle size distribution of different soil samples was determined by dispersing the sample with sodium carbonate sodium hydroxide and determining different size particles by sedimentation with pipette method. The percentage is given in Table I.

Table I

Determination of particle size

Sample No.	Rock No.	Percentage of sand	·002 per cent	·005 per cent	·01 per cent	(·02 + ·03 + ·05)	Remarks
31	4	21·10	14·5	22·0	17·0	27·04	From a field away from the rock near Bhakrala Railway station
34	4	20·0	10·5	15·0	15·0	40·91	Soil material deposited on the rock near Bhakrala Railway station
35	5	22·35	11·55	17·75	17·7	30·79	Samples taken from the top of the rock, on a hillock at a distance of 18 miles from Jhelum
39	5	9·80	15·0	21·1	30·5	23·71	Sample taken from the base of the hillock at a distance of 18 miles from Jhelum
44	5	2·02	18·0	24·2	34·0	22·22	Far away from the above from an arable field near the hillock
49	6	1·9	20·49	29·50	39·2	19·01	From the foot of the hillock at a flat surface near Jhelum at a distance of 95 miles from Lahore
51	7	2·75	16·0	23 80	32·7	25·95	10 feet away from the rock (black sand stone) near Kharian
54	7	2·05	19·20	21·0	28·0	30·12	Away from the rock (sand stone) on a slope
55	7	5·14	20·50	22·0	30 45	22·1	From an arable field at the foot of the hill
60	8	12·70	22·29	19·2	24·3	21·50	Sample taken from a field on a slope near the rock at village Malheri, Pathankot
61	8	18·5C	23·1	20·41	27·31	10·68	Taken after two fields at lower level than 60
64	8	3·35	10·5	15·55	18·45	48·12	Far away from the above fields near a Nallah

For the ultimate analysis of the soil and parent material the powdered samples of each were completely fused in a platinum crucible with fusion mixture. The contents were dissolved in hydrochloric acid and made up to the required volume with distilled water. The various components were determined in the usual way. The results are given in Table II.

TABLE II

Analysis of soil components

Sample No.	SiO_2	$Fe_2O_3+Al_2O_3$ (R_2O_3)	CaO.	MgO.	$SiO_2/Fe_2O_3+Al_2O_3$
Rock No. 4	25·48%	6·0 %	64·8 %	3·6%	4·245%
7	19·20	5·4	79·6	3·4	3·574
Soil No. 31	67·0	5·7	27·30	1·20	11·86
34	68·9	4·15	26·20	1·05	16·6
35	62·0	3·2	35·45	0·75	19·3
39	66·2	4·0	28·69	1·25	13·8
44	68·15	4·95	26·5	1·15	13·8
49	57·1	7·1	35·2	0·95	8·04
51	61·05	7·24	36·23	0·81	8·3
54	56·8	5·7	36·65	1·25	9·96
60	54·1	6·5	37·42	1·04	8·34
64	55·14	4·7	38·17	0·96	11·7

Total base exchange capacity was determined by ammonium carbonate method. The results obtained are given in Table III.

TABLE III

Determination of total base exchange capacity

Soil No.	Total exchangeable bases, m.e./100 gm.	$CaCO_3$ per cent	*p*H	Total solids per cent
C.S. 31	6·4	14·97	8·86	0·10
34	8·4	12·90	9·01	0·09
35	7·7	13·85	8·81	0·10
39	10·0	19·32	8·99	0·14
44	1·2	20·90	8·59	0·13
49	2·9	17·55	8·72	0·13
51	2·2	17·90	8·80	0·20
54	1·4	17·05	8·69	0·20
60	1·36	12·23	8·69	0·19
61	2·5	10·0	8·69	0·19
64	2·5	11·37	8·78	0·18

The carbonates content was determined by titrating the soil suspended in distilled water against standard sulphuric acid using Bromothymol Blue as indicator. The results are recorded in Table III.

Total solids of soils were determined by measuring electrical conductivity of 1 : 15 soil water suspension. The results are given in Table III. *p*H values of 1 : 15 soil water suspension as determined by *p*H meter are given in Table III.

Discussion

A comprehensive study of the mechanism of soil formation reveals that the rock is first converted into soil material under the influence of disintegration and decomposition processes. The material thus formed is made up of inorgan c material which is mainly passive. It forms the upper mantle of the consolidated rock and does not always remain in place where it is formed through the weathering agencies. It is picked up by forces such as melting snow, running streams or wind and redeposited at other places. When this material comes in contact with the factors, which influence, control and develop organic life transformation into soil sets in. The transition may be represented as :

Rock→Parent→Soil

Weathering materials soil forming factors

Climate, vegetation, topography, plant, an animal organism and time have been since long recognised as the soil forming factors. The nature of the soil depends mainly upon the type of soil formers which have been consistently influencing the pattern of soil development. One type of rock may give rise to different types of soil under diversified set of soil formers. Likewise different rocks may form one type of soil under a common set of soil formers. The texture of the soil produced is an index of soil development. It may be very coarse, coarse, fine and very fine depending on the stage of transition.

The area from which rocks were collected lies in the zone which is not affected by monsoon. The annual rainfall is less than 30 inches and temperature is very high during summer. It is not covered by vegetation.

It is expected that the soil formed from a limestone rock under such environments shall contain an excess of salts and calcium carbonate. The base-exchange capacity would be low and the silica would form a major part of the soil. It would also be deficient in organic matter and soil reaction would be on the alkaline side.

Results in Table III show that all soil profile contains excess of carbonates and has high salt content. Results given in Table I show that the soil contains higher percentages of coarser particles. The base-exchange capacity is also low and the soils have *p*H near about 9 (Table III) which shows that the soils are highly alkaline. Thus all the properties of soils of an arid region are manifested, and the presumptions are confirmed. The same rock would have produced a reverse type of soil if the area would have been in a region of sufficient rainfall and covered by vegetation.

It would be observed (Table I) that the percentage of finer particles increases with the distance from the parent rock. The silica sesquioxide ratio of weathered material is higher than that of the parent rock in all the cases but possesses no regular relationship. This shows that the weathered material is being removed from the parent material more by wind erosion than by water action. The sample No. 64 has a low percentage of finer soil material and is an exception to the general trend of distribution of particles of varying sizes of relation to distance

from the parent rock. This can evidently be attributed to the site being in the proximity of a stream where the possibility of water action is manifested. Although calcium oxide content of the weathered material is lower than that of the parent rack but its percentage is sufficiently high to show that final stage of decomposition has not been reached. The wind action appears to remove along with the weathered material the undecomposed or partially decomposed rock particles. This is the reason of having an irregular variation in the composition of soil material with respect to its proximity with the parent rock.

REFERENCES

Dokuchaev (1950). *Pedology by Joffe*. J. S. Second edition, Pedology publications, New Burnswick, New Jersey, P. 124

Marbut, C. F. (1935). Soils of the United States. *U. S. Dept. Agric.* Atlas of American Agriculture

Hilgard, E. W. (1914). *'Soils'*. The Macmillan Company, New York

Hilgard, A. (1897). *Uber verwittering*-svorgange bei Kerystallinischen landw Jahrah, **8**. 1-11

—— (1897). As above

Hissink, D. J. (1938). The reclamation of the Dutch saline soils and their further weathering under humid climatic conditions of Holland. *Soil Sci.* **45**, 83-94

Blockliger, G. (1931). *Mikro bio logische Untersuchungen an verwitternden Schrattenkalkfet sen*, Thesis, E. T. H. Zurich, Switzerland

Puri, A. N. *Bhai Lal, M. Amin, Bulletin* 175, Agricultural Research Institute

—— (1935). *Soil Sci.* **40**, No. 2

—— (1935). *Soil Sci.* Vol. **40**, No. 5

Puri, A. N. and Asghar, A. G. (1938). *Soil Sci.* **45**, 477.

A METHOD OF ESTIMATING THE LOSS CAUSED BY BLAST DISEASE OF RICE

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ALTHOUGH 'blast' disease of rice caused by *Piricularia oryzae* Cav. is the most serious disease of rice in India and is known to cause extensive damage to rice in some seasons, yet no reliable method has been evolved for an objective assessment of loss caused by the disease. However, on the basis of the observed severity of the incidence in large scale sampling surveys, it is possible to estimate the loss caused, provided an idea of probable relationship of loss in yield with any given intensity of disease incidence is known.

Studies are in progress at Central Rice Research Institute from 1951 to find out the relationship between observable symptoms of blast disease of rice and the extent of loss associated with its incidence. Blast manifests itself on rice as (i) leaf spots, mainly in the seedling and tillering phases and as (ii) "neck infection" (i.e., infection of the principal node in the panicle below the branches bearing the ears) at the time of flowering. Of the two phases, incidence of neck infection is associated with direct loss in yield due to formation of chaffy grains and breaking off of the ear-heads at infected node. In this investigation an attempt was made to estimate the extent of loss associated with the neck infection phase of the disease.

Material and Methods

The data in the study were collected from four different field experiments, conducted during the years 1951-1954, in which natural infection due to blast was sought to be reduced with different spraying treatments. The incidence of infection in the experimental plots was estimated by suitable sampling as given below and correlated with the yield of the plots.

There were two sets of spraying treatments : one in which different fungicides were applied four times in the season (Experiment I and II) and second in which the fungicide, Bordeaux mixture (5·5 : 50) alone was sprayed at different stages of crop growth (Experiment III and IV). Details of the treatments are given in Table I.

TABLE I

Details of the fungicidal treatments employed to bring about variation in incidence of blast in experimental plots

Experiment No.	Fungicidal Treatment	Time of application
I.	(1) Bordeaux 5 : 5 : 50	4 times in a season 2 before and 2 after flowering
	(2) Do. 2·5 : 3·5 : 50	do.
	(3) Perenox 0·5 per cent	do.
	(4) Control	
II.	(1) Bordeaux 5 : 5 : 50	do.
	(2) Perenox 0·5 per cent	do.
	(3) Coppesan 0·5 per cent	do.
	(4) Cupravit 0·5 per cent	do.
	(5) Control	
III and IV.	(1) Bordeaux 5 : 5 : 50	do.
	(2) do. do.	2 times, 1 before and 1 after flowering
	(3) do. do.	2 times, both before flowering
	(4) do. do.	2 times, both after flowering
	(5) Control	

In the first three experiments, Co. 13, a highly susceptible variety of 120 days duration and in the fourth, a moderately susceptible variety, T. 1145 of 140 days duration were used. For inducing heavy incidence of blast, seedlings were planted late (mid-August) and manured at 60 lb. N per acre (20 lb. N as basic green manure and farmyard manure and 40 lb. N as ammonium sulphate applied 10-15 days after transplanting).

Observations on the incidence of neck infection were taken at the time of harvest. The plot size was 500 sq. ft. in Experiment I, and 300 sq. ft. in other three experiments. Each plot was divided into strata of about 100 sq. ft. each. From each stratum

two random sampling units of about 4 sq. ft. were selected and the number of neck infected and healthy tillers in each sample and the respective weights of grains obtained from them were recorded. The yield of individual plots was recorded and the percentage of neck infected tillers in each plot estimated. A border of one row was discarded in the experimental plots in fixing samples and in determining the plot yields.

Results

The data on yield and estimated mean percentage of neck infection per individual plot are presented separately for each experiment in Tables II-V. The percentage of neck infection in the experimental plots ranged between 2·5 to 71·5 in the different experiments.

The analysis of the data showed that the fungicidal sprays had brought down the neck infection and increased the plot yields significantly.

Regression of yield on neck infection

For the purpose of estimating the effect of disease incidence on yield, a simple linear relationship of plot yields with percentage of neck infection may be assumed. With such an assumption the regression function of yield on neck infection is :

$Y=\bar{Y}+b\ (X-\bar{X})$, where, 'b' is the simple regression coefficient of yield on neck infection, and $\bar{Y}$ and $\bar{X}$ are the means of the corresponding characters. The value of 'b' measures the change in yield for unit change in percentage neck infection.

Since there were significant differences between blocks in all the four experiments, the block effect was first removed, and then the sum of squares, sum of products of neck infection and yield were utilized for estimating the regression coefficient. The regression function of plot yield on estimated percentage of neck infection was calculated for each experiment, and as the plot sizes differed in the trials, the equations were multiplied by appropriate factors to make the results comparable. The regression equations obtained in the 4 experiments were :

Experiment I—$Y=1506{\cdot}06-13{\cdot}30\ X$

Experiment II—$Y=1731{\cdot}80-23{\cdot}43\ X$

Experiment III—$Y=2811{\cdot}95-23{\cdot}44\ X$

Experiment IV—$Y=1933{\cdot}69-22{\cdot}22\ X$

the pooled regression equation being $Y=1967{\cdot}95-18{\cdot}72\ X$, where Y is the expected yield in lb. per acre and 'X' is the percentage neck infection estimated by suitable sampling.

The regression coefficients in the different experiments and that for the pooled regression were found to be significant (Table VI).

It might be seen from the pooled regression that the estimate of loss for 1 per cent increase in neck infection is 18·72 lb. per acre which worked out to be 0·95 per cent within the ranges of incidence and yield obtained in the experiments.

TABLE II

The yield in oz. (Y) and the estimated mean percentage of neck infection (N) per individual plot (Variety—Co. 13)

Block	Treatments							
	A		B		C		D	
	Y	N	Y	N	Y	N	Y	N
1	182·00	35·20	173·00	23·70	153·00	32·60	131·50	58·00
2	213·50	29·50	171·75	31·50	183·00	27·50	118·50	40·90
3	206·00	25·70	163·00	43·70	153·50	36·60	111·00	31·40
4	184·50	14·00	168·00	24·20	170·50	40·00	136·50	37·60
5	173·75	25·00	167·50	19·90	148·50	20·10	111·50	53·20
6	189·50	13·70	179·50	28·20	174·00	33·80	99·75	71·50
7	207·00	11·40	205·00	12·80	195·00	15·30	149·00	24·20
8	205·00	13·30	204·00	9·95	189·00	24·90	140·75	27·50
9	222·50	12·70	168·00	25·00	203·00	9·90	141·00	33·70
10	227·75	9·30	205·50	13·80	187·50	12·40	167·25	19·60
11	179·50	11·40	181·00	15·60	149·00	15·00	125·75	24·80
12	209·00	23·30	186·00	12·80	194·00	15·20	122·50	25·50

Treatments : A—4 sprayings of Bordeaux mixture (5 : 5 : 50)
B—4 sprayings of Bordeaux mixture (2·5 : 3·5 : 50)
C—4 sprayings of Perenox (0·5 per cent)
D—Control (unsprayed).

TABLE III

The yield in oz. (Y) and the estimated mean percentage of neck infection (N) per individual plot (Variety—Co. 13)

Block	Treatments									
	A		B		C		D		E	
	Y	N	Y	N	Y	N	Y	N	Y	N
1	122·00	12·32	104·00	12·77	70·00	12·54	66·00	8·57	62·00	26·58
2	86·00	6·03	108·00	6·88	122·00	14·39	110·00	12·11	50·00	35·22
3	118·00	12·87	86·00	12·77	94·00	18·02	120·00	12·39	80·00	32·68
4	146·00	7·45	114·00	13·88	126·00	11·29	118·00	5·40	84·00	27·76
5	72·00	12·70	96·00	16·02	54·00	19·48	102·00	2·62	58·00	29·35
6	124·00	10·04	90·00	12·72	54·00	15·27	118·00	12·57	78·00	22·46
7	112·00	8·63	110·00	10·78	96·00	9·56	102·00	4·03	58·00	36·72
8	130·00	2·63	124·00	7·91	128·00	4·29	126·00	4·29	106·00	26·11

Treatments : A—4 sprayings of Bordeaux mixture (5 : 5 : 50), 2 before and 2 after flowering
B—4 sprayings Perenox (0·5 per cent), (5 : 5 : 50)
C—4 sprayings Coppesan (0·5 per cent), (5 : 5 : 50)
D—4 sprayings Cupravit (0·5 per cent), (5 : 5 : 50)
E—Control (unsprayed).

TABLE IV

The yield in oz. (Y) and the estimated mean percentage of neck infection (N) per individual plot (Variety—Co. 13)

Block	Treatments									
	A		B		C		D		E	
	Y	N	Y	N	Y	N	Y	N	Y	N
1	119·00	19·90	94·00	35·36	93·00	25·90	85·50	25·86	71·00	49·40
2	165·00	10·98	107·00	15·15	134·50	11·60	80·00	29·00	102·50	31·83
3	136·00	11·93	110·50	29·13	118·00	13·28	115·50	18·75	76·00	29·35
4	116·50	7·38	89·00	25·83	118·00	10·61	91·00	28·50	61·50	40·13
5	164·00	9·68	124·00	10·65	145·00	8·43	133·50	10·28	111·50	29·73
6	140·50	3·32	113·50	10·76	142·00	13·43	123·50	10·03	102·50	28·28
7	130·50	25·03	107·50	13·13	114·00	14·38	114·50	12·96	88·50	21·86
8	128·50	9·78	136·00	8·00	139·00	10·66	113·50	12·33	93·50	26·01

Treatments : A—4 sprayings of Bordeaux mixture (5 : 5 : 50), 2 before and 2 after flowering of the crop
B—2 sprayings of Bordeaux mixture (5 : 5 : 50), 1 before and 1 after flowering of the crop
C—2 sprayings of Bordeaux mixture (5 : 5 : 50), both before flowering of the crop
D—2 sprayings of Bordeaux mixture (5 : 5 : 50), both after flowering of the crop
E—Control (unsprayed).

TABLE V

The yield in oz. (Y) and the estimated mean percentage of neck infection (N) per individual plot (Variety—T. 1145)

Block	Treatments									
	A		B		C		D		E	
	Y	N	Y	N	Y	N	Y	N	Y	N
1	144·75	12·72	171·25	12·80	157·00	9·75	147·50	13·62	137·25	12·96
2	153·00	3·36	155·25	7·59	148·50	11·03	150·00	3·49	163·00	11·36
3	151·25	9·50	139·50	14·55	145·75	12·36	154·50	13·36	123·75	17·93
4	154·17	2·52	153·75	9·48	169·75	3·74	180·75	2·00	117·00	7·32
5	153·42	2·85	156·50	9·09	174·00	5·76	148·25	6·16	139·50	5·82
6	182·00	5·20	200·50	20·46	197·50	12·60	217·50	4·08	207·00	17·92
7	185·00	11·84	162·50	19·69	169·50	20·47	173·50	10·18	168·50	18·33
8	170·75	9·02	182·50	13·36	177·00	15·42	195·00	10·08	130·25	18·89

Treatments : A—4 sprayings of Bordeaux mixture (5 : 5 : 50), 2 before and 2 after flowering of the crop
B—2 sprayings of Bordeaux mixture (5 : 5 : 50), 1 before and 1 after flowering of the crop
C—2 sprayings of Bordeaux mixture (5 : 5 : 50), both before flowering of the crop
D—2 sprayings of Bordeaux mixture (5 : 5 : 50), both after flowering of the crop
E—Control (unsprayed)

TABLE VI

Test of significance of the regression coefficients in the different experiments and pooled regression coefficient

Source of Variation	Experiment I			Experiment II			Experiment III			Experiment IV			Pooled for all the experiments		
	D.F.	M.S.	F.	D.F.	M.S.	F.	D.F.	M.S.	F.	D.F.	M.S.	F.	D.F.	M.S.	F.
Due to regression	1	18650·46	36·16 **	1	7817·57	26·42 **	1	1196·65	5·66 *	1	8231·56	40·16 **	1	4185608·46	100·21 **
Due to deviation from regression	35	515·71		31	295·95		31	211·33		31	204·99		131	41767·49	
TOTAL .	36			32			32			32			132		

* significant at 1 per cent level

** significant at 5 per cent level

Discussion and Conclusion

In order to understand the probable relationship between disease incidence and the loss in yield associated with it, it was necessary to adopt a suitable technique to bring about different degrees of disease incidence on a crop grown under otherwise uniform conditions. Artificial infection, control of natural outbreaks by spraying, growing of varieties of uniform yield potential but of different susceptibility levels, comparison of the yield of a susceptible variety in epidemic and non-epidemic years are some of the common methods adopted for this purpose [Vasudeva and Gattani, 1951*].

Under Cuttack conditions blast appears in a fairly severe form in most seasons when a highly susceptible variety like Co. 13 is transplanted late, after the middle of August, and fertilised at 40-60 lb. N per acre. The disease can be checked to a large extent by spraying the crop with a protective fungicide. By varying the spray chemicals, their concentration, time and number of sprayings, a fairly wide variation in disease incidence ranging from 2·5 per cent to 71·5 per cent could be brought about in the experimental plots. Since all the other factors for growth and yield were uniform, it was reasonable to assume that any variation in yield in the plot was due to the infection present.

Differences in blast incidence might also be brought about through artificial infection, principally by varying the spore load used, etc. but in a field scale, infection is likely to succeed only when environmental factors are particularly favourable for the disease outbreak. Under these conditions natural infection will also appear readily and has to be kept under check so that the effect of artificial infection is not masked. In practice, therefore, it is easier to have differences in disease incidence in the experimental plots through partial control of natural infection as far as blast disease is concerned.

It is doubtful whether such a wide range of infection under fairly uniform conditions for growth and yield could be obtained either by growing resistant and susceptible varieties of similar yielding capacity or by comparing the yield of a susceptible variety over a number of seasons.

The most important conclusion obtained in this study is that the percentage loss in yield due to 1 per cent neck infection is approximately 1 per cent under the experimental conditions specified. The comparatively low values of the residual coefficient of variation obtained indicate that there exists a linear relationship between yield and neck infection for the range of infection obtained in the experiments.

The disease incidence, i.e. neck infection in the present instance in the experimental plots, was estimated by suitable sampling, and the estimated neck infection was correlated with the actual yield of plots in the study. When the regression function of yield of samples on sample neck infection was worked out, it was found that the estimate of loss obtained was considerably lower by this method. This

*Vasudeva, R. S. and Gattani, M. L. (1951). Assessment of losses caused by plant diseases. *Indian J. Agric. Sci.* **21**, pp. 409-412.

was probably due to the fact that sample yield was more variable than plot yield and, therefore, it is considered that correlation of estimated plot incidence with plot yield would be a more accurate estimation of loss caused.

Before the data on the relationship of yield and percentage incidence of neck infection could be utilised to estimate the loss in yield caused by blast in the country on the basis of observed disease incidence over wide areas, it is necessary to have further data on the relationship between infection and probable loss in varieties of different duration and susceptibility groups. This aspect of the problem as well as the loss caused by leaf infection phase of the disease alone and in combination with neck infection are under study.

Summary

The relationship of the severity of neck infection of blast with loss in yield due to the disease was investigated in four field experiments carried out during 1951-54.

A highly susceptible short duration variety, Co. 13, maturing in 120 days was used in three experiments while T. 1145, a moderately susceptible variety, was used in the fourth.

Variation in incidence of neck infection was brought about by checking the disease in some plots by spraying copper fungicides. The range of infection brought about by spraying was mostly between 2·5 to 71·5 per cent.

The percentage of neck infection in each plot was estimated by suitable sampling at the time of harvest, the yield of the plots was recorded, and correlation established between the yield of plots and the estimated percentage of neck infection.

The regression technique was utilised in assessing the loss due to a given degree of neck infection. The pooled data of the four experiments showed that the loss associated with a unit increase in neck infection was nearly 18 lb. per acre which worked out to be 0·95 per cent.

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MOSAIC DISEASE OF CARDAMOM AND ITS TRANSMISSION BY THE BANANA APHID *PENTALONIA NIGRONERVOSA* COQ.

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(With 3 Text-Figures.)

In the Bombay State, cardamom (*Elettaria cardamomum* Maton) is grown as a secondary crop in the spice gardens of North Kanara. Mayne [1951] estimated the total area under cardamom in the State to be near about 900 acres. The acreage in spite of a very favourable market is dwindling from year to year on account of the prevalence of the disease known as "Marble" or mosaic, and called *Katte* in the local language. According to Buchanan [1807] the yield from one acre of healthy crop (about 65 lb. of dry berries) at the present market price may be worth Rs. 500 to Rs. 600, but a diseased plantation in the second or third year may yield only a few pounds.

According to Mollison [1900] the cardamom plants degenerate after having grown for a long time under the same conditions of soils and climate. Desai [1914] recorded that the cultivators think it due to an inferior type of leaf manure. Van Bunren [1914] considered it to be a disease of unknown nature which rendered the plant unthrifty in 3 to 4 years. Sahasrabudhe [1917] ruled out climate, insect pests, fungus or bacterial organisms or defect in the soil due to exhaustion or accumulation of injurious salts as possible causes of the disease. Kulkarni [1924] and Anstead [1924] stated that the disease caused extensive damage to cardamom cultivation in south and propagation by means of rhizomes has been given up since the plants thus obtained have been found to be affected by mosaic. Sahasrabudhe and Bapat [1929] after a series of experiments concluded that *Katte* was induced by an unfavourable soil condition closely correlated with the presence of the protozoa of the *Colpidium striatum* (Stokes) type. They further reported that if the soil of the affected pits was heated in dry condition to 100° C and cardamom plants grown in it, a beneficial effect was produced, which was not noticed either by the addition of manures or by the treatment of soil by lime.

Majority of cardamom growers in North Kanara even up to this day have the conviction that the infection is the result of soil exhaustion which affects the plants when these are 3 to 4 years old and some improvement takes place when the diseased rhizomes are put in new soil and manured by leaves of *Phyllanthus emblica* L. later.

Mayne [1951] listed the localities in which the disease was then prevalent. Now it is found in practically 90 per cent of the cardamom plantations except in some spice gardens north of Sirsi (Hulgod and Mensi) though the cardamom plants in these localities have been grown continuously for over 30 years. Similar disease-free areas have also been recorded by Mayne in some localities in Mysore and Madras.

The incidence of disease in a new plantation is usually negligible but it may increase from 70 to 100 per cent in a three-year old plantation.

Since the disease was of a major importance to cardamom interests in South India, investigations on the nature of the disease and its methods of dissemination were started at Sirsi in 1941 and the results were briefly recorded in an earlier note [Uppal, *et al.*, 1945]. Detailed results of experiments on the study of host range and the identity of the virus are presented in this article.

Symptoms

The earliest signs of infection in the youngest leaf of a cardamom plant appear as few, slender, discontinuous stripes of pale green colour running more or less parallel to each other from the mid-rib to the margin. All growth subsequent to infection manifests these stripes which form a characteristic mosaic pattern in fully diseased leaves (Fig. 1). After sometime the mottling is noticed even on leaf sheaths. The inflorescence does not show any symptoms and there is no malformation of any part of the plant, though after sometime a gradual reduction in the leaf size and a marked dwarfing and thinning of the stool takes place.

If a plant is infected in the seedling stage or in the first or the second year, it is a total loss as further growth is markedly suppressed and almost fails to fruit. The older plants, however, take sometime to go down and may yield for one season. As the disease progresses, the older shoots fall out and die and are replaced by fewer pseudostems which are shorter and thinner and the yield during subsequent seasons is markedly reduced. Besides, these plants become a perpetual source of infection to the neighbouring healthy plants in the garden.

Material and Methods

All plants required for experiments were raised from seed inside the insect proof glasshouse. The source of virus was a fully diseased 4-year old cardamom plant. The aphid culture was reared on healthy bananas in a separate portion of the glasshouse.

The aphids were fed on diseased young leaves rolled in the form of funnels and kept in flasks full of water (Fig. 2). By this device it was possible to feed the required number and type of aphids for specified periods. For feeding on test plants, the two top leaves were rolled into a funnel with the help of fine thread and insects liberated inside. After the completion of the feeding time, plants were sprayed with nicotine sulphate.

Fig. 1. A=Healthy cardamom leaf
B and C=Diseased cardamom leaves

Fig. 2. Method for feeding aphids on diseased leaves

Experimental

Transmission of the disease

To examine the hypothesis put forward by Mollison [1900] and Sahasrabudhe [1929] that the disease was the result of soil sickness, adequate samples of soil were obtained from gardens where the cardamom plants had been diseased for over a decade and put in sterilized pots in the glasshouse. Healthy one-year old cardamom plants grown from seed were transplanted in these pots and allowed to grow. Out of dozens of plants grown in this manner, not a single one was diseased after 4 years. In another experiment, soil from the base of old diseased plants was thoroughly mixed with cowdung manure and leaves of *Phylanthus emblica* and diseased rhizomes planted in these pots inside the glasshouse. In spite of the best care bestowed on these, there were no signs of decrease in the severity of the disease.

Further, healthy one-year old cardamom plants from glasshouse were transplanted in pits dug in the middle of severely diseased plantation and covered with muslin cages. Controls were kept by allowing an equal number of plants to grow exposed. Within a couple of months all the unprotected plants showed symptoms of disease, but out of plants under cover, none became diseased even at the end of 6 months. These experiments conclusively proved that the soil was no factor in the production of *Katte* and that the disease was being transmitted through some other source.

The disease could not be transmitted through sap either with the pin prick method or with the aid of carborundum powder.

The disease was also not transmitted through seed.

Transmission tests were further carried out with the following four species of insects found breeding on cardamom plants :

1. Thrips (*Taeniothrips cardamomi* Iyer).

2. Jassid (*Erythroneura* sp.)

3. White fly (*Bemisia* sp.)

4. The banana aphis (*Pentalonia nigronervosa* Coq.)

Thrips, jassids, white flies and aphids were collected in large numbers from diseased cardamom plants and directly liberated on healthy seedlings in the glasshouse for varying periods. In other cases, they were fed on diseased plants for several days before liberation on test plants. Out of 134 plants inoculated with thrips, 42 plants with jassids and 54 plants with white flies, none became diseased. Transmission was, however, readily obtained through banana aphis. The data relating to transmission tests are summed up in Table I.

TABLE I

Transmission of cardamom mosaic by the banana aphid

Source of aphids	Feeding period on diseased plants	Number and type of aphid per test plant	Feeding period on test plants	Plants diseased / Plants inoculated
Diseased cardamom plants	—	15 to 20 wingless	48 hours	2/3
		20 to 30 wingless	48 hours	2/2
		10 winged and 10 wingless	24 hours	4/4
		20 winged	24 hours	5/5
		10 winged	24 hours	3/3
Healthy cardamom plants	—*Nil*—	20 wingless	24 hours	0/4
	6 hours	20 winged and 10 wingless	24 hours	3/3
	12 hours	20 winged	12 hours	3/3
		10 winged	12 hours	4/6
	24 hours	20 wingless	48 hours	2/4
	24 hours	20 wingless	24 hours	4/4
	24 hours	30 nymphs	12 hours	0/2
	24 hours	10 winged and 10 wingless	24 hours	5/5
	24 hours	20 winged and 10 wingless	24 hours	3/3
	24 hours	30 II instar nymphs	24 hours	3/5
	24 hours	50 II instar nymphs	24 hours	3/6

The aphids (*Pentalonia nigronervosa* Coq.) breeds abundantly throughout the year on banana plants which are grown extensively in all spice gardens. On cardamom, sizeable colonies of the aphis are found only during winter months (July to February). Cardamom plants bored by larvae of *Dichocrosis punctiferalis* and in a state of half decay or banana plants cut in the middle are preferred by aphids which colonise in the tunnels made by the borers or under the leaf sheaths.

Experiments were also conducted to determine whether the aphids collected from banana plants could also transmit *Katte*. The results of these tests are given in Table II.

TABLE II

Transmission of cardamom mosaic by aphids collected from banana plants

Source of aphids	Feeding period on diseased cardamom plants	Number and type of vector per test plant	Feeding period on test plants	Plants diseased / Plants inoculated
Banana plants in diseased garden	None	30 wingless	24 hours	0/3
	None	15 winged and 15 wingless	24 hours	0/4
	None	50 wingless	48 hours	0/3
	None	50 to 100 wingless	48 hours	0/3
	24 hours	30 wingless	48 hours	1/2
	24 hours	50 wingless	48 hours	1/2
	24 hours	50 wingless	72 hours	2/2
	24 hours	20 wingless and 10 winged	24 hours	3/3
Colonies raised on healthy bananas	24 hours	10 winged and 10 wingless	24 hours	4/5
	24 hours	30 wingless	24 hours	4/5
	48 hours	20 winged and 20 wingless	24 hours	4/4
	48 hours	60 nymphs	24 hours	2/4
	48 hours	100 nymphs	24 hours	3/5

The results show that banana aphid is the vector of cardamom mosaic virus.

Non persistence of the virus in the aphid

In order to study the persistence of the cardamom mosaic virus in the aphid vector, viviparous females (alates) were fed on diseased cardamom plants for 24 hours and then liberated in groups of 15 on healthy test plants where they were allowed to feed for 24 hours and then shifted to new plants till the number of aphids was reduced to 8 or less. After the destruction of nymphs with nicotine sulphate, the plants were kept under observation for two months.

The results presented in Table III show that the virus does not persist in the aphid vector and, therefore, it may be classed as a non-persistent virus.

TABLE III

Transmission of Katte *disease of cardamom by aphids after an infection feeding period of 24 hours*

Experiment No.	Serial No. of Aphid groups	Infection obtained in successive feedings after days														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
I	1	+	+	—	—	—	—	—	—	—	—	—	—	D		
	2	+	—	—	—	—	—	—	—	—	—	—	—	—	—	D
	3	+	—	—	—	—	—	—	—	—	—	—	D			
	4	+	+	—	—	—	—	—	—	—	—	—	—	D		
	5	+	—	—	—	—	—	—	—	—	—	—	—	D		
	6	+	—	—	—	—	—	—	—	—	—	—	D			
II	1	+	—	—	—	—	—	—	—	—	—	—	—	—	D	
	2	+	—	—	—	—	—	—	—	—	—	—	—	—	—	D
	3	+	+	—	—	—	—	—	—	—	—	—	—	—	D	
	4	+	—	—	—	—	—	—	—	—	—	—	—	D		
	5	+	—	—	—	—	—	—	—	—	—	—	—	—	—	D
	6	+	—	—	—	—	—	—	—	—	—	—	—	D		
III	1	+	+	—	—	—	—	—	—	D						
	2	+	—	—	—	—	—	—	—	—	—	D				
	3	+	—	—	—	—	—	—	—	—	—	—	D			
	4	+	—	—	—	—	—	—	—	D						
	5	+	—	—	—	—	—	—	—	—	D					

N.B.—(1) '+' Indicates positive infection

(2) '—' Indicates negative infection

(3) 'D' Denotes that the experiment was discontinued

Host range of the virus

From among the weeds that grow on the hill sides and in the arecanut gardens banana aphid was found breeding on *Colocasia* sp. and *Amomum* sp. Some of the *Amomum* plants showed mosaic infection resembling that on cardamom. Healthy rhizomes of these two species of plants were collected and allowed to grow in the glasshouse for one year to ensure their freedom from virus infection and then inoculated by viruliferous aphids. In addition, plants of *Curcuma longa* L., *Zingiber officinale* Rosc., *Allium sativum* L., *Maranta arundinacea* L., *Musa* sp. and *Cana indica* L., were also similarly inoculated. Out of these plants only *Amomum* sp. were infected and they showed symptoms of disease very much similar to those on cardamom (Fig. 3). From other plants attempts to recover the virus by aphids gave negative results.

Amomum plants were found to grow plentifully in the vicinity of some cardamom gardens under favourable moist conditions but the infection in nature was usually less than 0·5 per cent while the infection was 100 per cent in the plants found growing in the spice gardens.

Populations of *Pentalonia nigronervosa* from healthy colonies on banana plants were fed on young diseased *Amomum* leaves overnight and liberated on healthy cardamom seedlings in the glasshouse. Out of 24 plants inoculated with 15 to 20 aphids per plant, the disease appeared in 22 plants. In another experiment aphids collected from diseased *Amomum* plants in nature and liberated on 16 healthy cardamom seedlings transmitted the disease to all the plants showing thereby that the virus on *Amomum* sp. and cardamom is identical.

The commonest weeds in the spice gardens are *Ageratum conyzoides* L. and *Vernonia anthelmintica* L. Both are heavily infected throughout the year with *Anaraphis helichrysi* L. which produces a typical curling and malformation of the leaves. These plants also exhibit symptoms of virus infection which is transmissible by the white fly (*Bemisia tabaci* Gen.). Attempts to transmit this virus to cardamom through *A. helichrysi* and white fly gave negative results, nor could this aphid transfer the virus from diseased to healthy cardamom. In addition, *Myzus persicae* (Sulz.) collected from cabbage plants failed to transmit the cardamom mosaic.

Summary

The cardamom crop in Penninsular India suffers from a mosaic disease, the symptoms of which are irregular chlorotic streaks running from midrib towards the periphery of the lamina. The disease renders cardamom plantations commercially useless within a period of 3 years. The virus cannot be transmitted by mechanical means, but is readily transmitted by the banana aphid, *Pentalonia nigronervosa* Coq., which usually breeds on banana but also on cardamom during winter. The natural alternative host of the vector as well as of the virus is a species of *Amomum* growing wild. The virus is of nonpersistent type. The mosaic virus causing *Katte* or the " Marble " disease of cardamom (*Elettaria cardamomum* Maton), is a new virus unreported elsewhere.

Fig. 3. A=Healthy leaf of *Amomum* sp.
B and C=Diseased leaves of *Amomum* sp.

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REFERENCES

Anstead, R. D. (1924). *Report on the operations of the Department of Agriculture,* Madras Presidency for the official year 1923-24, pp. 41

Buchanan, F. (1807). *A journey from Madras through the countries of Mysore, Canara and Malabar.* **3**, 225.

Desai, D. (1914). A trip to the spice gardens of North Kanara. *Poona Agric. College Mag.* **6**(1) : 44-50

Kulkarni, C. S. (1924). Mosaic and other related diseases of crops in the Bombay Presidency. *Poona Agric. College Mag.* **16** : 6-12

Mayne, W. W. (1951). Report on cardamom cultivation in South India, *I. C. A. R., Bull.* No. 50 (Revised edition)

Mollison, J. W. (1900). Cultivation of the betel palm, cardamom and pepper in Kanara District of the Bombay Presidency with notes on the manures used in the spice gardens of that District. *Dept. Land Rec. and Agric. Bull.* No. 20

Sahasrabudhe, D. L. (1917). The spice gardens of Sirsi in North Kanara. *Dept. Agric., Bombay, Bull.* No. 83

——— and G. M. Bapat (1929). A study of the soils associated with the deterioration of the cardamom crop in North Kanara. *Dept. Agric., Bombay, Bull.* No. 157

Uppal, B. N., P. M. Varma and S. P. Capoor. (1945). A mosaic disease of cardamom. *Curr. Sci.* **14** : 208-209

Van Bunren, H. (1914). The problems of spice garden cultivation. *Poona Agric. College Mag.* **6**(2) : 113—118

Varma, P. M. and S. P. Capoor. (1953). "Marble" disease of cardamom. *Indian Fmg.*, **3** : 22-23.

ALTERNARIA LEAF SPOT AND FRUIT ROT OF BRINJAL

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(With 2 Text-Figures)

BRINJAL (*Solanum melogena* L.), popularly known as egg plant, is extensively cultivated for its fleshy fruit as a vegetable. *Alternaria solani* (E. & M.) Jones and Grout is the only *Alternaria* sp. that has been recorded on this host [Chester, 1893 ; Rands, 1917 ; Butler, 1918].

A leaf spot and fruit rot of brinjal, caused by a species of *Alternaria*, was observed to be doing severe damage in the botanical area of the Indian Agricultural Research Institute, New Delhi, during 1952-53. Since the symptoms produced by it were quite different from those of *Alternaria solani*, the present studies were undertaken to identify the pathogen and study its mode of transmission with a view to devise control measures.

Symptomatology

The disease first makes its appearance in young seedlings during the rainy season (July-August) which are blighted. They give a charry appearance and finally die out. In September, it attacks leaves and then spreads to fruits which rot and become unfit for consumption.

On leaves, the disease manifests itself as small, circular, brown-coloured, necrotic spots which gradually enlarge in size. The mature spots may assume irregular shape or remain circular. Concentric rings in target-board fashion, characteristic of infection caused by *A. solani*, are not formed. The spots are accompanied by a chlorotic halo. Finally, the spots coalesce which results into withering and shedding of the leaves (Fig. 1). Due to humid conditions prevailing at the ground level, lower leaves are first attacked and then infection spreads to upper leaves and fruits.

Lesions on fruits are first observed during February. They start as small (about $\frac{1}{2}$ cm. in size), concentric, dark brown and sunken spots. Colour of the lesions becomes olivaceous dark brown due to spore formation. Several lesions may coalesce and cover the entire surface of the fruit (Fig. 2).

Similar symptoms were also observed on tomato and potato leaves. After January, typical symptoms of *A. solani* were, however, found on potato and tomato leaves, but not on brinjal.

Fig. 1. Brinjal leaves affected by leaf spot disease

Fig. 2. Brinjal fruit affected by fruit rot disease

Isolation

Isolations were made from the diseased leaves of brinjal, tomato, and potato, which had been collected from the botanical area of I. A. R. I. and some neighbouring villages, by immersing small pieces in a 0·1 per cent solution of mercuric chloride for 1 to 2 minutes followed by a thorough washing in sterilized water. More than 95 per cent of the isolates yielded a species of *Alternaria*. Since all the resultant cultures were similar in appearance, one isolate each from brinjal, tomato and potato was single-spored for detailed study. Typical cultures of *A. solani* were, however, obtained from the concentric rings on the leaves of tomato and potato.

Pathogenicity

Young potted plants of brinjal, potato and tomato were inoculated with all the three isolates separately by spraying a heavy spore suspension both on injured and uninjured leaves. Injury to the leaves was made by the pinprick method. The inoculated plants were kept in a moist chamber for 48 hours and placed in the glass-house for the symptoms to develop. Suitable controls were maintained in each case. Results of such an experiment are given in Table I.

TABLE I

Pathogenicity tests with the three isolates

Pathogen	Percentage of infection on the leaves of					
	brinjal		potato		tomato	
	injured	uninjured	injured	uninjured	injured	uninjured
Brinjal isolate	60	26	55	23	50	20
Potato isolate	53	20	57	23	47	27
Tomato isolate	50	20	47	17	55	23

The data show that the three isolates can infect all the three hosts and that higher infections are obtained when the leaves are injured before inoculation, so that all the isolates are weak parasites.

Surface disinfected fruits of brinjal were also inoculated with the brinjal isolate with or without injury and kept in the moist chamber. Suitable controls were maintained. Fifty per cent infection was obtained in wounded ones only. Both in the artificially inoculated leaves and fruits, typical symptoms of the disease developed. Controls in all cases remained healthy.

Morphology

The hyphae are dark olive buff to buffy brown ; septate ; 3-6 μ wide. The conidiophores are concolorous with the mycelium ; septate ; 40-70 μ long and 3-6 μ wide ; erect ; branching or non-branching ; geniculate. On the host they arise in clusters from the dead spots, while on agar cultures they are formed singly as side branches on hyphae. The conidia are formed in chains, usually consisting of about 7-10 spores ; as a rule they are smooth when young and verrucose when matured, linear to obclavate ; dark olive buff in colour ; 1-7 transverse and 0-5 longitudinal septa ; size 20-26 μ × 7-18 μ. In culture the beak, when present, is really made up by the apical cell of the spore body alone, but on the host a true beak, which is longer and slender, is developed. On potato-dextrose agar, it produces a colony of 45 mm. diameter at 29°C. within 4 days, showing zonation of dark olive coloured rings alternating with pale olive areas, except near the periphery where the colour remains whitish. After about 8 days' growth, petri plates of 10 cm. diameter are completely covered with the colony assuming a sooty black colour, particularly in the central region. The medium turns pale brown.

Physiology

The conidia germinate equally well in tap and distilled water. They can also germinate in highly humid atmosphere (about 90 per cent) without the presence of actual water film. The germination is further stimulated by the use of sucrose. Conidia from the host start germinating after 4-6 hours, while those taken from a nutrient medium after 8-10 hours at 29°C. The fungus grows well on potato-dextrose, agar, oat-meal agar, rice agar, tomato juice agar, Richard's agar and Brown's synthetic agar. The optimum temperature for the growth of the fungus is 28°-29°C., the minimum and maximum being 4° and 45°C, respectively.

Host range and transmission

Solanum nigrum L., *S. aviculare* L., *Pyoscyamus niger* L., *Lycopersicon pimpinellifolium* Mill., *Datura stramonium* L., *Nicotiana tabacum* L., *Capsicum frutescens* L. var. *longum*, *Brassica oleracea* L. and *Zinnia* sp. were inoculated with the brinjal isolate and *A. solani* by the pin-prick method for host range study. *A. solani* was used as it is the only other *Alternaria* species so far recorded on brinjal. Plants of brinjal, potato and tomato were also inoculated simultaneously to ensure that conditions were suitable for successful infection. In addition to these three hosts, the brinjal isolate successfully infected only *Hyoscyamus niger*, whereas *A. solani* infected all the hosts except *Brassica oleracea* and *Zinnia* sp. The uninoculated control plants in each case remained healthy. Moreover, *A. solani* unlike the brinjal isolate, produced typical concentric rings on the leaves of all the hosts infected.

In the transmission studies, unsterilised seed obtained from infected fruit was sown in sterilised soil in pots and about 25 per cent seed germinated. Ungerminated seed was found to be rotting due to a species of *Alternaria* similar to the brinjal isolate. Cotyledons of the germinating seed were severely blighted and the seedlings that emerged from them were destroyed.

Identity

The delimitation of species in the genus *Alternaria* is based on size, colour, septation and shape of the spores as also on length of the beak, but these characters are very variable. The problem is further complicated by mutation, variation in morphology in culture and facultative parasitism, resulting in large host ranges. Recent workers [Elliot, 1917 ; Wiltshire, 1933 ; Neergaard, 1945] have, therefore, broad-based the earlier known species under various groups. The spore characters of the various *Alternaria* species recorded on Solanaceous hosts and of the brinjal isolate are compared in Table II.

TABLE II

Spore characters of Alternaria species recorded on Solanaceous hosts as compared to the species under study

Fungus	Spore size with beak (microns)	Av. length of beak (microns)	Shape of spore	Septation	
				Transverse	Longitudinal
A. solani (E. & M.) J. & G.	190-240 × 15-25	½ the length of spore or longer	Obclavate	4-19	1-4
A. tomato (Cke.) Weber	135 × 15	82	Obclavate to clavate	12-20	1-5
A. longipes	75-100 × 15-20	41	Clavate	3-7	1-2
A. tenuis Auct.	20-60 × 7-20	9	Linear to obclavate	2-7	1-3
Alternaria sp. (from brinjal, *tomato* & potato)	20-60 × 8-20	12	Linear to obclavate	2-8	1-3

It is observed that the *Alternaria* sp., isolated from brinjal, tomato and potato, is morphologically similar to *A. tenuis* Auct. and is quite distinct from the other *Alternaria* species recorded on Solanaceous hosts. The fungus understudy is, therefore, identified as *A. tenuis*.

DISCUSSION

The only species of *Alternaria* recorded on brinjal from various countries is *Alternaria solani* (E. & M.) J. & G., and there is a similar doubtful report by Butler [1910] from India. Butler considered *Macrosporium lycopersici* Plowr. and *M.*

tomato Cke. as synonyms of *A. solani*, but they are now regarded indentical with *A. tenuis*. Although *A. tenuis* is normally a saprophyte, it may act as a weak parasite on a large number of plant species and this is corroborated by the findings reported herein. This fungus has, however, not been previously recorded on brinjal.

Cross-inoculation tests have shown that the brinjal isolate also infects potato and tomato. Bhagwagar [1946] found a species of *Alternaria* on potato in India which, according to him, resembled *A. tomato* Cke. The latter species is now considered to be a synonym of *A. tenuis*. Thus it is reasonable, to assume that the fungus studied by us is the same as that of Bhagwagar.

Contaminated seed has been found to be a source of infection in seed beds. Treatment with seed dressing fungicides may, therefore, help in reducing the damage in the nursery stage.

Summary

Symptoms of a leaf spot and fruit rot disease of brinjal have been described in detail and the causal organism identified as *Alternaria tenuis* Auct. The optimum temperature for the growth of the fungus and for the germination of spores is found to be 28-29°C. Potato, tomato, and *Hyoscyamus niger* have been found to be the other hosts. The pathogen is seed transmissible.

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REFERENCES

Butler, E. J. (1918). *Fungi and disease in plants.* Thacker Spink and Co.

Bhagwagar, P. R. (1946). Early blight of potato in India. *Indian J. agric. Sci. 16 :* 296-301.

Chester, F. D. (1893). The ripe rot or anthracnose of tomato. *Rept. Delaware Agric. Exp. Sta.* pp. 111-115

Elliott, J. A. (1917). Taxonomic characters of the genera *Alternaria* and *Macrosporium*. *Amer. J. Bot.* 439-476

Neergaard, P. (1945). *Danish species of* Alternaria and Stemphylium

Rands, R. D. (1917). Early blight of potato and related plants. *Wiscon. Agri. Exp. Sta. Res. Bul.* 42

Wiltshire, S. P. (1933). The foundation species of *Alternaria* and *Macrosporium Trans. Brit. Mycol. Soc. 18.* 135-160

LODGING IN WHEAT

ON THE EFFECT OF NITROGEN, NITROGEN *PLUS* POTASH, SEED-RATE, AND DEPTH OF SOWING ON SOME MORPHOLOGICAL CHARACTERS IN RELATION TO LODGING IN TWO VARIETIES OF WHEAT

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LODGING is a problem of great concern for every cultivator, as it reduces the yield from 5 to 50 per cent, while harvesting becomes laborious and expensive. Introduction of non-lodging character in a variety is a very important consideration in the improvement of Indian wheats. Howard and Howard [1912] and Ramanujam [1950] emphasised that the high-yielding capacity combined with good standing power should be sought for while evolving new varieties, otherwise the high yielding varieties would lodge and result in lower yields. According to Welton and Morris [1931] the actual loss depends largely upon the completeness of falling, the stage at which it occurs and the subsequent weather conditions. Middleton [1903] observed 50 per cent reduction in yield due to lodging.

Causes of the lodging may be classified into four categories : (i) hereditary characters, such as weak straw with poorly developed mechanical tissue or varieties with inferior root system, as suggested by Percival [1921], Hall [1934] and Caffery and Carrol [1938], (ii) improper cultural methods such as unbalanced nutrient supply and heavy application of nitrogenous fertilizers [Harcourt, 1906], and thick sowing or heavy seeding [Gainy and Sewell, 1930], (iii) environmental conditions such as wet soil due to water logging, irrigation or rainfall followed by strong wind at any time after ear emergence and (iv) insect pests and fungus such as *Cercosporella* foot-rot [Fellows, 1948], take-all disease [Hanley, 1942], Hessian fly [Walster, 1920], or Sawfly [Atkins, 1938].

Attempts have been made for a long time to find out suitable indices for lodging on the basis of which the breeder could evolve a resistant variety. Almost all the workers agree on the importance of the root system in lodging ; but none has recommended it as a suitable index for lodging resistance. Several other morphological characters have been studied but varying results have been obtained by

different workers under different environmental conditions. In recent years more attention has been paid to mechanical measurements such as breaking strength of straw, culm density, pulling resistance, etc. Lodging is the net result of the combined effect of several environmental factors and plant characters and as such it is difficult to correlate it with a single character. Studies on lodging in Indian wheats were taken up during 1949-50 (i) to find out suitable indices for distinguishing the lodging resistant varieties, (ii) to determine the effect of nitrogen supply on lodging, (iii) to find out whether potassium if supplemented with high level of nitrogen could check lodging as found by Tubbs [1930] and Moore [1949], and (iv) to study the effect of different seed rates and depths of sowing on lodging.

Material and Methods

A field experiment was laid-out with 12 combinations of the following treatments.

Fertilizers	Seed rates	Depth of sowing
f_1=Control	S_1=60 lb./ac.	d_1=Normal depth of sowing 1—2 inches
f_2=80 lb. N/ac.	S_2=100 lb./ac.	
f_3=80 lb. N/ac.+80 lb. K_2O/ac.		d_2=Deep sowing 3—4 inches.

$3 \times 2 \times 2 = 12$.

The treatments were randomly distributed in each of the four replicates. The plots were subdivided for two varieties, viz. N.P. 165 and N.P. 710 which were known to differ in standing power. For convenience in sampling the two varieties were placed in 2 strips across all the four replications. As this layout did not conform to the regular split plot pattern, the data were analysed on randomised block basis separately for each variety. Data for percentage lodging was first transformed to degrees before working out the analysis of variance.

There were four replicates.

Number of rows of each variety : 5

Distance between rows : 1 foot

Length of row : 19 feet

Distance between varieties : $1\frac{1}{2}$ feet

Size of main plot : 19 ft. $\times$ 10 ft. = 190 sq. ft.

Size of sub-plot : 19 ft. $\times$ 5 ft. = 95 sq. ft.

Sowing was done on the 8th November, 1949. For normal depth of sowing, a hand plough was used and for deep sowing, a spade. Germination was uniform. Deep sown seed germinated about two days later. Respective quantities of fertilizers were broadcast on the 29th November, 1949 and all the plots were irrigated

on the same day, taking care that water did not overflow the bunds from one bed to another. Subsequent irrigations were given on the 21st February and the 21st March 1950.

Fortnightly tiller counts and plant height (in cm.) within each sample unit of 2 ft. length were recorded. Lodging generally occurs after ear emergence which usually takes place within the first fortnight of February. Plant samples consisting of about 15 plants per sample were taken from each treatment from the 16th March 1950 to March 28, 1950 for determination of the following characters : (i) number of internodes in the mother shoot, (ii) diameter at the middle of the lowest internode in mm., (iii) length of the lowest internode in cm., (iv) fresh weight of tops (shoots), (v) fresh weight of the lowest internode and (vi) breaking strength of the lowest internode.

For determining the breaking strength of straw, a simple method was adapted. Pieces 6 cm. in length were cut from the middle of the lowest internode. The piece was then placed across a wooden ring of diameter 5·6 cm. supported on a stand. A pan was suspended by means of a wire of a fixed length, with a hook, from the middle of the piece. Sand was allowed to run on the pan from the funnel through a rubber tubing attached to it until the piece bent and gave way. The amount of sand along with the pan, wire and hook were weighed to the nearest gram and the weight was taken as the breaking strength of straw.

For anatomical study, the lowest internode of nearly the same diameter was cut out, fixed in formalin acetic acid solution and then finally preserved in 70 per cent alcohol. Free hand sections of the material were cut and stained in safranin red and counterstained by light green in clove oil and permanent slides were made. The following observations were taken : (i) diameter of the culm ; (ii) number of vascular bundles ; (iii) number of cell layers of sclerenchyma ; and (iv) thickness of sclerenchyma and its location.

Before harvesting the lengths of rows with lodged plants were measured in each bed. The lodging percentage was worked out on area basis. Ten samples each of one foot length of erect and lodged plants from each variety were taken and the grain threshed out. From this, grain weight per unit length was calculated for lodged and erect plants. Actual loss due to lodging under each treatment was calculated as follows : the ratio of weight of grain from lodged/erect plant = 0·795 in N.P. 165, proportion of lodged row length/erect plant row length = 1 : 2·8, actual yield = $1\times 0{\cdot}795 + 1\times 2{\cdot}8 = 3{\cdot}595$, calculated yield = $1 + 2{\cdot}8 = 3{\cdot}8 \times 1 = 3{\cdot}8$. Therefore, loss due to lodging = 3·800 — 3·595 = 0·205. Correlation coefficients were worked out between the mean values of lodging percentage and of different characters under the different treatment combinations.

Experimental Results

Lodging occurred on the 9th and 21st February and 15th March, 1956, after the rainfall or irrigation followed by a strong wind. The data on percentage lodging are given in Table I.

TABLE I

Percentage lodging under different treatments

	N.P. 165	N.P. 710
f_1	0·0	0·3
f_2	40·5	53·3
f_3	32·7	41·9
SE	±3·40	±3·58
C.D. 5 per cent	9·72	10·24
1 per cent	13·09	13·78
s_1	17·2	29·9
s_2	31·6	33·7
d_1	22·4	35·6
d_2	26·4	28·1
SE	±2·78	±2·92
C.D. 5 per cent	7·95	
1 per cent	10·70	

Effect of nitrogen. Lodging occurred only in those beds which received nitrogen or nitrogen combination treatments. High nitrogen supply to the soil has been observed to cause lodging by Harcourt [1906], Hanley [1942], Moore [1949] and others.

Effect of potash. Potash in combination with nitrogen gives strength to the stem and reduces lodging, as it helps in carbon assimilation. Excess of available carbohydrate over nitrogen results in developments of thick cell walls and stiff straw. Similar results have been reported by several authors like Wright [1896], Purivis [1919], Tubbs [1930], Piacco *et al.* [1940], Nightingale [1943] and others.

In the present experiment, addition of potash did not reduce lodging significantly. This may probably be due to higher dose of nitrogen in comparison to potash or adequate quantity of potash in soil. Hanley [1942] has also reported that if there

is no deficiency of potash in the soil the application of additional quantity would not materially affect the standing power of the crop. Galchenko [1940] and Donald [1935] observed that kainite did not help the standing power to the slightest extent.

Seed rate. As early as 1865, Sachs [1882] observed lodging when the stand was too thick. In the present experiment lower seed rate significantly reduced lodging only in N. P. 165.

Sowing depth. Depth of sowing did not show any significant effect on lodging. Ramiah and Dharmalingam [1934] and Welton and Morris [1931] also did not find any difference in the stand (lodging) due to different depths of sowing.

Varietal difference. Variety N. P. 710 seemed to have lodged more than N.P 165.

The data on morphological characters of plants are listed in Table II.

TABLE II

Average data of morphological characters of plant samples

Variety	Treatments	Final tiller No./pl.	Height of the shoot in cms.	Diameter of the lowest internode in m.m.	Fresh wt. of 6 cm length of the lowest internode in mgmo	No. of internodes per (mother shoot) culm	Length of the lowest internode
N.P. 165	f_1	1·79	129·6	3·125	69·7	5·0	7·43
	f_2	2·49	124·3	3·050	56·0	5·2	9·42
	f_3	2·65	126·7	3·025	56·8	5·3	8·97
SE		±0·11	±1·599	±0·029	± 0·26		
C. D. 5 per cent		0·3146			0·744		
	s_1	2·60	127·3	3·08	61·4	5·1	8·90
	s_2	2·02	126·4	3·05	60·2	5·2	8·32
	d_1	2·39	127·8	3·10	60·8	5·2	7·78
	d_2	2·23	126·0	3·03	61·1	5·2	9·43
SE		±0·09	±1·30	±0·024	±0·214		
C. D. 5 per cent		0·2574			0·612		
N. P. 710	f_1	2·09	123·9	3·125	60·4	5·7	7·46
	f_2	2·54	121·8	3·175	65·3	5·7	8·82
	f_3	2·57	121·1	3·175	56·3	5·7	9·05
SE		±0·103	±1·86	±0·033	±0·277		
C. D. 5 per cent		0·294			0·79		
	s_1	2·69	121·8	3·22	59·4	5·7	8·39
	s_2	2·11	122·8	3·10	55·3	5·8	8·50
	d_1	2·53	123·2	3·23	58·4	5·7	9·02
	d_2	2·27	121·4	3·18	56·3	5·8	7·86
SE		±0·084	±1·52	±0·027	±0·226		
C. D.		0·240		0·077	0·646		

Final tillers. It is clear from the data that the fertilizer treatments, and low seed rate gave a significantly higher number of tillers in both the varieties. Similar results have been obtained by many workers. Singh and Alam [1944] in wheat, Brady [1934] in cereals and several other have reported increase in tillering under wider spacing.

Deep planting apparently had no effect on tillering. Singh and Alam [1944] and Welton and Morris [1931] also did not find any difference in tiller number under deep and shallow planting.

No correlation was found between tiller number and lodging under different treatments. Clark and Wilson [1933] also did not find any correlation between lodging and rate of tillering of wheat varieties.

Height. There was no significant difference in height due to treatments and it had no correlation with lodging ; variety N.P. 165 was taller than N. P. 710 by a few centimeters and it showed less lodging. Ramiah and Dharmalingam [1934] also did not find correlation between height of culm and lodging, whereas Atkins [1937] and Galchenko [1940] found positive and significant correlation between height of the main culm and percentage lodging.

Internodal study. Average number of internodes per culm did not differ much from treatment to treatment. Average number of internodes correlated with lodging percentage only in N.P. 165, and no relationship existed between number of internodes and lodging percentages in case of N.P. 710. Hamilton [1941] also did not find any correlation between the number of internodes and lodging. The length of the lowest internode was more under fertilizer treatments than under the control. The length of the lowest internode correlated with lodging only in case of N.P. 710, the correlation being positive and significant at 5 per cent P (0·435). Ramiah and Dharmalingam [1934] in rice, Hall [1934] in maize and Hamilton [1941] in oats also did not find any correlation between the length of the lowest internode and lodging, whereas Atkins [1937] and Brady [1934] found positive and significant correlation.

Diameter of the lowest internode. There was no significant difference in diameter due to treatments or varieties. Variety N.P. 165 showed negative and significant correlation at 75 per cent level with lodging percentage, the correlation coefficient being 0·45 ; whereas in the case of N.P. 710, the correlation was positive but not significant. Garber and Olson [1919], Smith [1934], Atkins [1937] and Harrington and Waywell [1950] did not find any correlation, whereas Hamilton [1941] found negative and significant correlation between diameter of the lowest internode and lodging.

TABLE III

Fresh weight of per unit length of the lowest internode, fresh weight of mother shoot, breaking strength and ratio of breaking strength/top weight

Variety	Treatment	Av. Fresh wt. in mg./unit length of the lowest internode	Fresh wt. in gm. of top	Breaking strength in gm.	Ratio of breaking strength and F. wt. of top
N. P. 165	f_1	69·7	8·19	818·7	99·96
	f_2	56·0	8·62	634·7	72·47
	f_3	56·8	8·54	675·8	79·1
	SE=	±0·26	±0·34	±8·1	
	C. D. 5 per cent	0·7436		23·17	
	s_1	60·9	8·89	759·6	85·43
	s_2	60·8	8·01	659·9	82·38
	d_1	62·2	8·26	677·9	82·07
	d_2	59·4	8·66	741·5	85·62
	SE=	±0·214	±0·28	±6·6	
	C. D. 5 per cent	0·612	0·8008	18·88	
N. P. 710	f_1	60·4	8·48	701·7	82·78
	f_2	55·3	9·98	640·7	64·19
	f_3	56·3	9·69	671·5	69·27
	SE=	±0·277	±0·09	±5·0	
	C. D. 5 per cent	0·79	0·257	14·3	
	s_1	59·4	9·74	707·1	72·59
	s_2	55·3	9·02	635·5	70·45
	d_1	58·4	9·83	666·9	67·84
	d_2	56·3	8·93	675·7	75·66
	SE=	±0·226	±0·073	±4·14	
	C. D. 5 per cent	0·646	0·2088	11·84	

Weight per unit length. The fresh weight per unit length of the lowest internode was higher in control plants than in fertilizer treated plants.

The fresh weight per unit length of the lowest internode correlated negatively and significantly with lodging in case of N. P. 165 only at 5 per cent P. The correlation coefficient being =0·617. Atkins [1938] also found very high correlation between weight per unit length of the culm and lodging.

Dry weight per unit length. Control plants had significantly higher dry weight per unit length of the lowest internode than the fertilizer treated plants. Seed rate and depth of sowing gave no difference in dry weight per unit length. The dry weight per unit length of culm was also negatively and significantly correlated with lodging in the case of both the varieties. (The 'r' value being —0·608 and —0·506 for N. P. 165 and N. P. 710 respectively.) Welton and Morris [1931] attached great importance to dry weight per unit length of the culm as a factor associated with lodging.

Fresh weight of tops. Nitrogen and nitrogen combination treatments gave more fresh weight of tops than the control. As excessive nitrogen caused the luxuriant vegetative growth and succulent tissues, with increased water content. Fresh weight of tops correlated with percentage lodging positively, and significantly only in case of N.P. 710.

Breaking strength. Variety N. P. 165 had significantly higher breaking strength in control plants than fertilizer treated plants. (The higher breaking strength of straw in control might be due to more development of mechanical tissues.) Seed rates and depths of planting did not affect the breaking strength of straw significantly. Variety N. P. 710 had lower breaking strength of straw than N. P. 165.

The breaking strength of straw correlated negatively but not significantly with lodging in case of both varieties. Clark and Wilson [1933] and Smith [1934] also did not find breaking strength of straw as a suitable index for lodging, whereas Atkins [1937] found in winter wheat the breaking strength of the lowest internode as quite a suitable index for lodging.

The tendency to lodge would seem to depend on two factors, viz. (*i*) strength of the lowest internode and (*ii*) the top weight. The relation between the ratios of breaking strength to fresh weight of the tops and lodging were worked out and are given in Table III. Variety N. P. 165 has a higher ratio than N. P. 710 thus accounting for the lesser lodging tendency of the former variety. The other treatments showed no pronounced effect. The ratio correlated very highly with percentage lodging in both the varieties (for N.P. 165 the correlation coefficient was —0·838 and for N. P. 710 —0·828 significant at 1 per cent). Therefore, a complete evaluation of the relationship between breaking strength and lodging must be considered in view of weights of the tops. This is in agreement with the view of Clark and Wilson [1933] and Smith [1934].

Anatomical studies of the lowest internode. Data are given in Table IV. The data clearly show that treatments affect the development of certain tissues.

TABLE IV

Anatomical characters of the lowest internode

Variety	Treatment	No. of cells in sclerenchyma	Thickness of sclerenchyma layer in microns	Total No. of vascular bundles
N. P. 165	f_1	5·00	2·05	48·7
	f_2	3·70	1·77	52·0
	f_3	3·85	1·40	51·7
	C.D. at 5 per cent	0·695	0·3216	..
	s_1	4·23	1·82	50·4
	s_2	4·13	1·66	51·3
	S. Em.	±0·17	±0·078	
	d_1	4·53	1·91	50·0
	d_2	3·83	1·57	51·7
	C.D. at 5 per cent	0·568	0·260	
	Mean	4·1	1·74	..
N. P. 710	f_1	6·2	1·99	59·7
	f_2	4·0	1·89	59·7
	f_3	4·2	1·51	58·7
	C.D. at 5 per cent	0·792	S.Em. ±0·17	..
	s_1	4·6	1·86	60·9
	s_2	5·0	1·75	57·9
	S.Em.	±0·21	±0·139	..
	d_1	5·0	1·98	59·5
	d_2	4·6	1·62	59·3
	S. Em.	+0·21	+0·139	..
	Mean	4·8	1·79	..

Total number of vascular bundles. There was no significant difference in the number of vascular bundles due to treatments. This is in agreement with the view of Garber and Olson (1919). Hamilton (1941), however, found that the number of vascular bundles in the parenchymatous region was evidently greater in the strong strawed varieties than in the weak strawed varieties of oats.

Number of cells in sclerenchyma layer.—The number of cells in the sclerenchyma layer were significantly more in control than in nitrogen or nitrogen combination. The number of cells in sclerenchyma layer correlated significantly and negatively with percentage lodging in the case of both the varieties (the value of 'r' being —0·776 and —0·807 for N. P. 165 and N. P. 710 respectively).

The correlation between various characters and lodging percentage were worked out and given in Table V.

TABLE V

Correlation between different characters and lodging percentage

Character	N. P. 165	N. P. 710
1. Final tiller number	+0·331	+0·507
2. Height of the main shoot	—0·617	—0·212
3. Number of internodes per main culm	+0·453	+0·083
4. Length of the lowest internode	+0·16	+0·43
5. Diameter of the lowest internode	—0·45	+0·25
6. Fresh weight per unit length	—0·617	—0·39
7. Dry weight per unit length	—0·608	—0·526
8. Breaking strength of the lowest internode	—0·313	—0·295
9. Breaking strength/fresh weight of tops	—0·838	—0·828
10. Total number of vascular bundles	+0·647	—0·151
11. Number of cells in sclerenchyma	—0·776	—0·807
12. Fresh weight of tops	—0·044	+0·844

It is clear from the Table V that the best indices for lodging for these varieties are fresh and dry weight of unit length of the lowest internode, ratio of breaking strength of the lowest internode to fresh weight of the top and the number of cells in sclerenchyma.

Effect of lodging on yield under different treatments.—Lodging is known to cause a reduction in yield and loss in yield due to lodging was calculated according to the method already described. As application of nitrogen increased lodging, the increase in yield obtained by application of nitrogen was partially reduced by lodging. Table VI gives the quantity of grain lost due to lodging under different treatments.

TABLE VI

Loss due to lodging

Treatment	N. P. 165			N. P. 710		
	Yield in lb. per acre	Loss per acre in lb. due to lodging	Corrected yield in lb. per acre	Yield in lb. per acre	Loss per acre in lb. due to lodging	Corrected yield in lb. per acre
f_1	1496·0	000·0	1496·0	1616·0	000·0	1616·0
f_2	2319·0	291·6	2610·6	2087·0	526·9	2613·9
f_3	2049·0	231·4	2280·4	1886·0	381·7	2267·7
s_1	1762·0	203·1	965·1	1642·0	478·0	2120·0
s_2	1572·0	319·0	1891·9	1506·0	430·4	1936·4
d_1	1807·0	264·9	2071·0	1722·0	561·4	2283·4
d_2	1529·0	258·0	1787·0	1426·0	347·1	1773·1
Mean	1688·0	261·4	1929·4	1574·0	454·2	228·2

The loss was greater in N. P. 710 than in N. P. 165. Higher seed rate caused greater loss of grain than lower seed rate in N. P. 165, while normal depth of sowing produced greater loss than deep sowing in N. P. 710.

Further when the results were calculated for the increase in grain per pound of nitrogen applied, it was found that each pound of nitrogen gave an increase of 10·3 lb. of grain in N. P. 165 and 5·9 lb. of grain in the case of N. P. 710. The increase in yield was reduced by application of nitrogen *plus* potash as compared to nitrogen alone.

The problem of application of nitrogen thus becomes complicated as it involves both gain due to growth as well as loss due to lodging. Attempts should be made to determine the time of application and dose of fertilizer so that maximum yield can be realised by such application with minimum loss.

Conclusions

Application of nitrogen in heavy dose as 80 lb. nitrogen per acre results in more lodging.

Application of potash with a heavy dose of nitrogen does not reduce lodging.

Dry weight of per unit length of lowest internode, (*b*) the number of schlerenchyma cells and (*c*) the ratio of breaking strength of lowest internode to fresh weight of tops show negative and significant correlations with lodging in case of both the varieties and, therefore, are considered as suitable indices of lodging.

Summary

Studies on lodging were carried out under field conditions to see the effect of nitrogen, notrogen *plus* potash and of seed rate and depth of sowing on lodging and some morphological characters of two wheat varieties, N. P. 165 and N. P. 710.

Application of heavy dose of nitrogen hindered the development of mechanical tissue, reduced straw strength and made the tops heavy and thus increased lodging in both the varieties under all nitrogen combination treatments.

Potash in addition to nitrogen did not decrease lodging significantly.

Variety N. P. 165 showed comparatively lesser extent of lodging with low seed rate than with high seed rate, while N. P. 710 showed no difference in lodging at both seed rates. Depth of sowing had no effect on lodging.

Several plant characters were studied for the suitable indices for lodging and only the following could be correlated with the percentage lodging in case of both the varieties : (1) fresh and dry weight per unit length of the lowest internode (negative) ; (2) the number of cells in sclerenchyma (negative) ; (3) breaking strength of the lowest internode/fresh weight of tops (negative).

The loss in yield due to lodging was the highest under the nitrogen treatment in both the varieties. Addition of potash along with nitrogen reduced loss to slight extent. Loss due to high seed rate was more in the case of N. P. 165 than in N. P. 710. Depth of sowing showed no effect.

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REFERENCES

Atkins, I. M. (1937). Relation of certain plant characters to strength of straw and lodging in winter wheat. *J. Agric. Res.* **55** (2) : 99-120

—— (1938). A simplified method for testing the lodging resistance of varieties and strains of wheat *J. Amer. Soc. Agron.* **30**(4) : 309-313

Brady, J. (1934). Some factors influencing lodging in cereals. *J. Agric. Sci.* (England) **24** : 202-232

Caffery, M. and Carrol, P. T. (1938). Lodging in oats. *J. Dept. Agric.* **35** : 25-38

Clark, E. R and Wilson, H. K. (1933). Lodging in small grains. *J. Amer. Soc. Agron.* **25** : 561-572

Donald, G. (1935). Factors affecting the standing power of oat. *Scot. J. Agric.* **18** : 34

Fellows, H. (1948). Falling of wheat culms due to lodging. *Circ. U. S Dept. Agric.* No. 737

Gainy, P. L. and Sewell, M. C. (1930). Indications that available nitrogen may be limiting factor in hard winter wheat production. *J. Amer. Soc. Agron.* **22** : 639-641

Calchecko, J. N. (1940). Lodging of spring wheat under irrigation. *Bull. Acad. Sci. USSR. Cl. Sci. Math. ct.*

Garber, R. J. and Olson, P. J. (1919). A study of the relation of some morphological characters to lodging in cereals. *J. Amer. Soc. Agron.* **11** : 173-186

Hall, D. M. (1934). The relationship between certain morphological characters and lodging in corn. *Univ. Minn. Agric. Exp. Sta. Tech. Bull.* **103**

Hamilton, D. G. (1941). Certain oat culm characters and their relationship to lodging. *Sci. Agri.* (Ottawa) **21**(10) : 646-76

Hanley, F. (1942). Lodging in cereals. *Agric. J. Min. Agr.* **48** : 212-13

Harcourt, R. (1906). Lodged grain. *Thirty-first Ann. Rept. Ont. Agri. Col. Expt. Sta. Farm* **1905**

Harrington, J. B. & Waywell, C. G. (1950). Testing resistance to shattering and lodging in cereal. *Sci. Agri.* **30**(2) : 51-60

Howard, A & Howard, G. L. C. (1912). On the inheritance of some characters in wheat. *Mem. Dept. Agri. Indian Bot. Ser.* **5** : 1-46

Middleton, W. (1903). Fifth Annual Report of Field Experiments, Cambridge, from "*Wheat in India*" by Howard, and Howard, G.L.C.

Morre, H. I. (1949). The problem of lodging. *Agriculture J. Min. Agric.* **56** (7) : 314-316

Nightingale, G. T. (1943). Physiological chemical function of potassium in plant growth. *Soil* **55** (1) : 73-78

Percival, J. (1921). *The wheat plant*, a monograph. Duckworth co. London

Piacco, R. L. and Jallethamantonelriso (1940). Lodging of rice plant. *Italica Agric.* **77**(8) : 565-572

Purvis, O. N. (1919). The effect of potassium salts on the anatomy of *Dactylis glomerata*. *J. Agric. Sci.* **9** : 338-65

Ramiah, K. and Dharmalingam, S. (1934). Lodging of straw and its inheritance in rice. *Indian. J. Agri. Sci.* **4** : 880-894

S. Ramanujam (1950). Lodging in cereals and the possibilities of breeding for resistance. *Indian J. Genetics and Plant Breeding, Vol.* **10**, No. 2 : 78 to 95 (1950)

Sachs, J. (1882). *The physiology of plants*

Singh, S. S. and Neck Alam (1946). The effect of certain external factors upon the growth of wheat. *Proc. Ind. Acad. Sci.* **19B** (3) : 29-64

Smith, D. C. (1934). Correlated inheritance in oats and reaction to diseases and other characters. *Minn. Agri. Ext. Sta. Tach. Bull.* **103**

Tubbs, F. R. (1930). Physiological studies in plant nutrition II. Effect of manurial deficiency upon the mechanical strength of barley straw. *Ann. Bot.* **44** : 147-160

Walster, H. L. (1920). Formative effects of high and low temperature upon the growth of barley —a chemical correlation. *B. N. Gaz.* **9** : 97-126

Welton, F. A. (1928). Lodging in oats and wheat. *Bot. Gaz.* **85** : 121-151

Welton, F. A. and Morris, W. H. (1931). Lodging in oats and wheat. *Ohio Agri. Expt. Sta. Bull.* **471**

Wright, N. P. (1896). *Report of Scotland Agr. Col.* **31**

CASHEW GRAFTS AND LAYERS EXCEL SEEDLINGS

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(With 3 Text Figures.)

At the Cashew Research Station, Kottarakkara, Kerala State, the growth and performance of three-year old cashew grafts have excelled those of the layers and seedlings of equal age. The layers, though inferior to grafts in growth vigour, are decidedly superior to the seedlings. Eight numbers under each of grafts, layers and seedlings of one year growth were planted during June 1954 for an observational trial. During the current season, all the eight grafts have yielded fruits, while five air-layered plants and all the eight seedlings are yet to commence bearing. With regard to flowering, while all the grafts and layers have flowered, the seedlings are yet to commence flowering. The comparative growth measurements of the vegetatively propagated plants and seedlings are furnished in Table I.

Table I

Growth and performance of cashew grafts, layers and seedlings recorded on 20-1-1957

Date of planting	No. planted	Average height	Average girth	Average spread	Flowering and fruiting
June 1954—					
Grafts	8	9 ft. 10 in.	28 in.	13ft. × 12ft.	All have fruited ; average yield 33 nuts
Layers	8	7 ft. 1 in.	17 in.	10ft. × 9ft.	All have flowered ; only three have fruited ; average yield 13 nuts
Seedlings	8	8 ft. 3 in.	15 in.	12ft. × 11ft.	None have flowered or fruited.

The superiority of grafts over layers and seedlings in point of height, girth spread and early bearing nature are clearly brought out from the above figures. The layers, however, excel seedlings in tree girth and earlier flowering and fruit

FIG. 1. An inarched plant

FIG. 2. An air-layered plant

FIG. 3. A seedling plant

production. The above results indicate the advantages of the selection of cashew inarches and layers for planting as compared to the usual practice of seed planting *in situ*. Such a selection, not only confers the means of perpetuating superior progenies, but also is helpful to raise vigorous growing plants which commence bearing early.

Figs. 1, 2 and 3 show a three-year old inarched plant, air-layered plant and seedling plant.

Season for inarching

Cashew seedlings, raised in suitable containers made of coir husk, hill grass or bamboo, when they attain pencil thickness, can be used for inarching. The inarches can be separated from the mother plants in about $2\frac{1}{2}$ to 3 months time. A preliminary trial to determine the best season for inarching was conducted at the Kottarakkara Research Station. The period September to October gave cent per cent success. Inarches made during this period can be separated during December-January and will be available for planting during June-July.

Air layers

A ring of bark $\frac{1}{4}$ to $\frac{1}{2}$ inch width is removed from pencil thick shoots of the previous season's growth. The ring is made about a foot below the terminal growing point. The cut portion is tied round with twine to prevent the ends from joining together. The ringed portion is then covered over with a handful of moist sand and saw dust well mixed and covered with a piece of alkathene film of 5 in. $\times$ 6 in. dimension and tied at both ends. The shoots produce roots at the cut portion and can be separated in two-and-a-half months from the parent plants. An observational trial conducted to select the optimum season for air-layering under local conditions in 1954-55 revealed that this method of propagation is successful throughout the year. The heavy rainfall period from June to August, gave poor results of 30 to 40 per cent success, while the best results were got (90 to 100 per cent success) during February to April.

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TIN CONTENT OF SOME CANNED JACK FRUIT PRODUCTS

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THE tin content of processed foods packed in cans is of considerable importance from the point of view of the health authorities. The published literature on the subject is, however, very meagre. Goss [1917] reported valuable facts regarding the tin content in several classes of canned fruits and vegetables. Adam and Horner [1937] made a systematic survey of the tin content of English canned fruits and vegetables and reported that fruits and vegetables in lacquered cans rarely contained more than 40 mg. of total tin per kg. even after long storage, the soluble tin not exceeding half this amount. After animal and human feeding experiments, Buchanan and Schryver [1908] suggested two grains of tin per pound of food (285 mg. per kg.) as the maximum permissible limit in foods in England. The recommendation is accepted in that country as the recognised maximum limit for the tin content of canned foods. Whatever may be health significance attached to this limit, it represents a liberal allowance for the can manufacturer considering the great improvements in canning technology during the past 40 years. In India according to the Fruit Products Control Order, 1955, the maximum permissible limit is 143 mg./kg. Recently, Monier Williams [1950] has summarised the latest knowledge regarding tin in food, its determination by gravimetric, volumetric and colorimetric methods and its absorption and excretion by the human organism.

Very little data are available regarding the tin content of Indian canned fruits and vegetables. Siddappa and Rao [1953] reported the tin content of some important varieties of Indian canned mangoes and gave preliminary results about canned pummelo, grape fruit, pears and jack bulbs. Jack fruit canned in 40° Brix syrup in a plain A $2\frac{1}{2}$ size can and processed under pressure was found to contain only 11·4 mg./kg. tin after a storage period of 6 months. In view of the very limited data available about the tin content of canned jack fruit products, this study was taken up in the course of investigation on development of various products from this fruit.

Materials and methods

Canned ripe jack fruit in syrup and raw jack packed alone or in combination with other vegetables in curried style were prepared by the methods described by Bhatia, *et al.* [1955] and Jain, *et al.* [1953]. They were stored at 2-5°C room temperature (24-30°C) and 37°C and the tin content determined after different periods of

storage. The tin content of jack fruit squash packed in plain and lacquered cans was determined after 60 weeks of storage at room temperature. The same lots of plain and lacquered cans were used in all the experiments to avoid batch to batch variations in the tin plate.

Fruit and syrup were weighed (total about 100 gm.) in the same ratio as found in the canned product and digested by the usual wet oxidation method [A.O.A.C., 1950]. In the digests tin was estimated colorimetrically using the dithiol reagent and a Lovibond Tintometer according to the procedure of Dickinson [1944]. The results were expressed on wet weight basis.

RESULTS AND DISCUSSION

The tin content of canned jack fruit is given in Table I. This data is based on the analysis of single cans only. The results based on averages of 2-4 cans analysed at a time were also similar.

A sample of canned jack fruit packed in 35° Brix syrup containing 0·15 per cent citric acid had 202·5 mg./kg. tin after a storage period of 3 years at room temperature. It had light orange colour and slightly cooked taste and was not fit for consumption. Tin content of other canned jack fruit products like jack fruit squash and canned curried jack is given in Table II.

A careful study of Tables I and II will show that the temperature of storage is the most important factor determining the tin content of canned jack products. Dissolution of tin is more at 37°C than at room temperature or 2-5°C. In Table I the values of tin in canned jack fruit packed in plain cans and stored at room temperature or 2-5°C from 20-47 weeks ranged from 11·2 to 99·6. Similar values for samples stored at 37°C varied from 160·1-437·5. It will be seen that the values are highly variable in different cans. The probable reason for this unusually large variation may be the uneven coating of tin layer on the steel plate which is likely to occur in the dip method of manufacture of tin plate adopted in this country. Data based on averages of 2-4 cans also showed the same trend of results. In all cases where the values of tin were more than 200 mg./kg. the product had turned brown, had cooked taste and were quite unfit for consumption.

Products packed in lacquered cans have given lower tin values than those packed in plain cans because lacquering protects the tin plate against corrosion by the fruit acids. These cans are, however, not quite suitable for canning of jack fruit as the products packed in these give some peculiar resinous taste. Moreover, an intense local corrosion may take place in isolated spots which are not protected by the lacquer and the can may develop perforations within a short period of storage. Such a thing is not likely to occur in plain cans where corrosive action will be spread over a large surface.

It will be seen from Table II that raw jack fruit canned in curried style, alone or in combination with other vegetables dissolved negligible quantities of tin even after 63-66 weeks of storage at room temperature. The *p*H of the medium does

The substitution of the wet digestion method instead of the dry ashing technique did not introduce any large errors in the Dithiol estimation of tin in the samples.

TABLE I

Tin content of canned jack fruit packed in plain and lacquered cans during storage at different temperatures

(Data based on the analyses of single cans)

S. No.	Description of sample	Type of can	Storage temperature	Tin content of the contents of the can mg./kg.		
				After 20 weeks	After 33 weeks	After 47 weeks
Set I	Packed in 50° Brix syrup containing 0·5 per cent. citric acid	Plain	Room temp.	71·6	..	54·6
	do.	do.	37°C	228·7	..	..
	do.	do.	2-5°C	99·6	..	48·7
	do.	Z. Lacquered	37°C	..	84·4	..
	Packed in 50° Brix syrup containing 0·75 per cent. citric acid	Plain	Room temp.	71·4	..	67·0
	do.	do.	37°C	..	..	160·1
	do.	do.	2-5°C	54·0	..	58·5
	do.	Z. Lacquered	37°C	..	59·7	..

TABLE I—*contd.*

S. No.	Description of sample	Type of can	Storage temperature	Tin content of the contents of the can mg./kg.		
				After 20 weeks	After 33 weeks	After 47 weeks
Set II	Packed in 50° Brix syrup containing 0·5 per cent. citric acid	Plain	Room temp.	11·2	..	58·9
	do.	do.	37°C	244·1	..	295·6
	do.	do.	2-5°C	65·4	..	..
	do.	Z. Lacquered	Room temp.	..	..	42·2
	do.	do.	37°C	34·9	..	78·1
	Packed in 50° Brix syrup containing 0·75 per cent. citric acid	Plain	Room temp.	35·1	..	41·1
	do.	do.	37°C	268·1	..	437·5
	do.	do.	2-5°C	..	..	..
	do.	Z. Lacquered	Room temp.	44·5	..	41·1
	do.	do.	37°C	54·6	..	103 7

TABLE II

Tin content of canned jack fruit squash and canned curried jack during storage at room temperature

(Data based on the analyses of single cans)

Sl. No.	Description of sample	Type of can	Period of storage (weeks)	Tin content mg./kg.	*p*H of contents	Condition of can
1	Curried style jack+onions packed in ordinary gravy	Plain	66	10·5	4·65	Blackening of tin plate, stained feathering
2	do.	SR Lacquered	66	8·0	4·48	Lacquer unaffected
3	Curried style jack+onions packed in gravy containing tamarind	Plain	64	0·0	4·10	Blackening of tin plate, stained feathering
4	do.	SR Lacquered	64	10·5	4·10	Lacquer unaffected
5	Jack+cauliflower (3 : 1) packed in gravy containing tamarind	Plain	63	0·0	4·10	Stained feathering
6	Jack+field beans (3 : 1) packed as above	do.	63	10·5	4·25	do.
7	Jack+potato (3 : 1) packed as above	do.	63	0·0	4·25	do.
8	Jack+tomato (3 : 1) packed as above	do.	63	10·5	4·10	do.
9	Jack fruit squash having 52° Brix and 1 per cent citric acid	do.	60	187·5	2·98	do.
10	do.	Lacquer	60	75·0	3·02	Lacquer unaffected

not seem to be responsible for the low values since at similar *p*H values the tin content of canned jack fruit is considerably more. While studying tin content of canned vegetables, Portnov [1936] pointed out that the fat content of preserved foods retarded the solution of tin. As the canned curried style vegetables contain about 4 per cent fat, it may very likely be a contributing factor responsible for their low tin content.

From the results reported in the Tables I and II and their discussion, it is safe to assume that tin content of canned jack products stored at ordinary room temperatures for about a year will rarely exceed a value of 100 mg./kg. which is below the maximum limits permitted in U.K. and India.

Summary

The tin content of canned jack fruit products stored at room temperature and 2-5°C was found to be far below the permitted limit of 285 mg./kg. in U.K. At 37°C, the values were comparatively higher and in samples, which had considerably darkened, the values in some cases exceeded the limit. Negligible quantities of tin were dissolved in raw fruit canned in curried style.

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REFERENCES

Adam, W. B. and Horner, G. (1937). *Ann. Rept. Fruit and Vegetable Preserv. Res. Sta.* Campden, Univ. of Bristol, pp. 14-20

A. O. A. C. (1950). *Official Methods of Analysis*, 7th Edn. Published by the Association of Official Agricultural Chemists, Washington 4, D.C.

Bhatia, B. S., Siddappa, G. S. and Lal, G. (1955). Development of products from Jack fruit. Part I —Canned jack fruit, frozen canned jack fruit and jack fruit jam.; *Indian Food Packer*, **9** (9) 8-11

Buchanan, G. S. and Schryver, S. B. (1908). *Report of the Inspector of Foods*, Local Self Government Board No. 7, H. M. Stationery Office, London

Dickinson, D. (1944). *Ann. Rept. Fruit and Vegetable Preserv. Res. Sta.* Campden, Univ. of Bristol, pp. 46-52

Goss, B. C. (1917). *Ind. Eng. Chem.* **9**, 144

Jain, N. L., Bhatia, B. S. and Lal, G. (1953). Canning of Curried Vegetables; *Science and Culture*, **19**, 76

Monier-Williams, G. W. (1950). *Trace Elements in Food*; Chapman and Hall, London, pp. 138-161

Portnov, Y. L. (1936). *The content of tin in canned vegetables*; Konservanya prom., No. 4, 16-21

Siddappa, G. S. and Rao, G. R. (1953). The Content of some important Indian Canned Mangoes and other fruits; *Indian J. Hort.* **10**, 49-55.

REVIEW

DIRECTORY OF WHEEL AND TRUCK TYPE TRACTORS PRODUCED THROUGHOUT THE WORLD

Published by the F.A.O., Rome (1955). Price $ 3·00.

THIS Directory furnishes information on wheel and truck type tractors produced by 143 firms situated in 13 different countries such as the U.K., the U.S.A., France, Germany, Italy, Sweden, Czechoslovakia, Austria, Australia, Canada, Japan, Spain and Switzerland. The matter has been presented systematically under three different chapters. While the first chapter contains the addresses of manufacturers, the second and the third chapters have been completely devoted to technical information on wheel and truck type tractors respectively. Details of tractors from 8 H.P. to 37 H.P. and over have been included and they have been classified in four horse power categories for the wheel tractors and five separate horse power categories for truck type designs.

General information on tractors, namely, the overall width, length, weight, ground clearance, turning radius, etc. have been compiled for almost all the tractors that are included.

Information on tractor engine specifications, viz. maximum horse power, revolutions per minute, fuel consumption, working speeds of the tractor in the forward and backward directions, etc. has been furnished on the basis of the manufacturer's rating. Some of these figures have been obtained from official publications also.

Details regarding the fuel consumption per hour, drawbar pull, etc. of a few tractors have not been given although these figures are considered important from a technical point of view. Further, these figures should preferably be based on Standard tests conducted in the laboratory and field and not on the manufacturer's rating as has been done here in some cases.

So far, such publications on technical information on tractors have been brought out by only a few organised tractor testing centres of the West. In this connection the publications of the " Nabraska Tractor Testing Laboratory of the U.S.A." and the " National Institute of Agricultural Engineering U.K. ", are worth mentioning. These publications include the specifications as well as the performance date of different makes of tractors that have been tested by these institutions under their standard test conditions.

The publications of the Nabraska Laboratory and the National Institute of Agricultural Engineering, mentioned above, cover only their respective countries, viz. U.S.A. and U.K. There are no such publications from other tractor producing countries and as such the present volume, although it does not fully cover the data of tractors of all the countries of the world, is likely to be useful as a general informative guide, particularly to countries like India where tractors are purchased from many different countries of the world.

The information given in the Directory is of a general nature and gives an idea of the type and general specifications of tractors produced in most of the tractor producing countries of the world. Before actually ordering for or selecting a tractor, more detailed information and technical specifications will have to be called for. In some cases, the price of the tractor works has been mentioned, but this is likely to change from time to time. (R.V.M.)

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